APPRAISAL OF DIFFERENT DECOLORATION SYSTEMS FOR CLARIFIED BANANA FRUIT JUICE

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ABSTRACT

The present investigation entitled "Appraisal of Different Decoloration Systems for Clarified Banana Fruit Juice." was conducted with a broad objective of developing decoloring system for clarified banana juice. To do so the effects of various decoloring variables such as type of adsorbent, adsorbent concentration, adsorption temperature and adsorption time on the color value, TSS, turbidity and pH of the treated clarified banana juice were evaluated. Two adsorbents (bentonite and powdered activated charcoal), with respective concentration (0.3, 0.5, 0.7 and 0.9; 0.3, 0.5, 0.7, 0.9, 1.5, 2.0, 3.0, 5.0, 7.0 and 9.0 %, respectively), three adsorption temperatures (30, 45 and 60 °C) and two adsorption duration (30 and 60 min) were investigated. Bentonite had little effect in decoloration of clarified banana juice and other quality parameters. Significant effect was seen of the variables for powdered activated charcoal on the quality of the final product. Color value was the maximum (35.14) for the 9.0 % concentration of powdered activated charcoal and at 60 °C adsorption temperature and 60 min adsorption time and was the minimum (11.10) for the 0.3 % concentration of powdered activated charcoal, 30 °C temperature and 30 min adsorption time. The TSS was the lowest (12.4 °Brix) for 9.0 % PAC concentration, 30 °C adsorption temperature and adsorption time of 30 min. The turbidity was maximum (5.78 NTU) at 1.5 % PAC concentration, at lowest adsorption temperature (30 °C) and lowest adsorption time (30 min) but minimum (0.32 NTU) at 9.0 % PAC concentration, 60 °C adsorption temperature and 60 min adsorption duration. Based on the above results, optimized values of the decoloration variables obtained within the range of the parameters studied were; type of adsorbent: PAC, adsorbent concentration: 9.0 %, adsorption temperature: 60 °C and adsorption duration: 60 min. The final decolored clarified banana juice had 35.14 color value, 12.8 °Brix TSS, 0.76 NTU turbidity, 4.52 pH, 0.1 % titrable acidity and 4 mg/100g ascorbic acid.

Key words: Decoloration, PAC adsorption, bentonite, banana, clarified banana juice, color value, turbidity, TSS.

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CERTIFICATE

This is to certify that the thesis entitled "**APPRAISAL OF DIFFERENT DECOLORATION SYSTEMS FOR CLARIFIED BANANA FRUIT JUICE.**" submitted by **SHWETA ANIL WATTAMWAR** in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **Food Processing Technology** to the Anand Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision.

Place : Anand **(D. C. Joshi)**

Date: /10/2010 **Major Advisor**

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LIST OF ABBREVIATIONS AND SYMBOLS

Abs	absorbance
ANOVA	analysis of variance
CBJ	clarified banana juice
C.D.	critical difference
C.V.	coefficient of variance
cps	centipoise sec
Da	dalton
DE	total color difference (color value)
DF	degree of freedom
g	gram (s)
GAC	granular activated charcoal
gal/lit/sq.ft	gallon per liter per square feet
h	hour (s)
kDa	kilo dalton
kg	kilogram
m	meter
µg	microgram (s)
mg	milligram (s)
min	minute (s)
ml	milliliter
mm	millimeter
MS	mean of squares
NTU	nephelometric turbidity units
nm	nano meter
N	Normal
PAC	Powdered activated charcoal
pH	potenz hydrogen
rpm	revolution per minute
s	second (s)
SEM	standard error of mean
TSS	total soluble solids
%	percent
°C	degree Celsius

CHAPTER I

INTRODUCTION

India is one of the most important fruit producing nations in the world, accounting for about 10.4 percent of all fruits and nearly 40 percent of tropical fruits produced globally. Banana and mango are the two major tropical fruits produced in India with an agreeable flavor and high nutritional value. India is the world's leading producer of banana and mango, the world's most widely-traded horticultural products, with respective contribution of 24 % and 40 % of world production, respectively.

Banana at 81.3 million tonnes in year 2007 was the second largest produced fruit after citrus, contributing about 16 % of the world's total fruit production (FAO, 2009). It has originated from eastern Asia, spread to all over the world through hybridization and is cultivated in over 130 countries, along the tropics and subtropics of Capricorn

Banana fruit is consumed by millions of people around the world as part of their daily diet for nutrient enrichment in a variety of ways: mostly as fruit worldwide, staple food in most African countries and as ripe fruit, green vegetable and for other therapeutic uses in eastern parts of the world. As banana has low sodium and fat content, it is also consumed by people who are intolerant to salt. It is rich in carbohydrate, antioxidants like dopamine and minerals like potassium and calcium, and caters to the calorific need of many developing countries (Kanazawa and Sakakibara, 2000; Mohapatra *et al*., 2010a).

The fruit also has antimicrobial and therapeutic properties. It is rich in ascorbic acid (4.5–12.7 mg/100 g fresh mass), β-carotene (50–120 µg/100 g fresh weight), citric acid and malic acid, which can act synergistically as flavour enhancer when added to fruit juices and other finished products (Mohapatra *et al*., 2009; 2010a). It can be consumed in ample amount to meet the current recommended daily allowance to evade vitamin A and C deficiency apart from providing resistance to chronic diseases like cardiovascular dysfunction and muscular degeneration at old age and muscle cramp for athletes (Englberger *et al*., 2003; Wall, 2006; Oguntibeju, 2008) without bothering much about fat, as it is low in fat (0.1 %) and sodium content (17 mg/100 g).

Now a days, there is a rising trend of consuming natural and fresh fruit juices. Juices from fruits obtained by the extraction of cellular juice from fruits are products for direct consumption. Fruit juices are categorized as those without pulp (‘‘clarified’’ or ‘‘not clarified’’) and those with pulp (‘‘pulps,’’ ‘‘purees,’’ and ‘‘nectars’’). Tropical fruit juice can be the best source of healthy nutrients. Since decades, various fruit juices like grape and apple have been used as the base juice for the blending purpose as they are the cheapest sources available.

The fruit juices have certain color pigments which change the color during processing / storage and thus reduces the market value of the juices. It is therefore, necessary to remove some or all of the coloring bodies present in the juice while at the same time avoiding the excessive loss of turbidity or pulp particles which imparts opalescence to the juice or avoiding excessive changes in the organoleptic properties such as viscosity, acidity, sucrose content etc. (Regling *et al.*, 1981).

Product stability during storage is an important aspect that needs to be understood in any product development work. Although juices are bright and clear after microfiltration, changes in color and development of undesirable haze and turbidity are common side reactions that seriously compromise commercial acceptability. Post-bottling haze formation has long been a problem associated with fruit juices, especially clarified fruit juices. Appearance of haze and browning in juices are often wrongly perceived as deterioration of quality. Besides, it detracts product appearance and is undesirable.

Various pre- and post processing are now available to reduce the risk of change in turbidity and decoloration of juices within the intended shelf life. Stabilization of beverage by means of gelatine and bentonite is a widespread treatment in the juice industry (Dik & Ozilgen, 1994). Adsorption is commonly used approach to purify contaminated fluids that are unacceptable in smell and taste. Typical adsorbents being used for the removal of polyphenols and brown color for fruit juices include activated carbon, gelatine/bentonite, casein, ion-exchange waxes and polyvinylpolypyrrolidone (Giovanelli and Ravasini, 1993).

Banana juice is quite cheaper and could be made available throughout the year. Fruit juices such as strawberry and other exotic juices are in great demand but costly. The fruit industry is interested in blending the available low-cost juices with those having high cost. The main limitation of blending is the undesirable change in color and flavor of the final product. Decolored and deflavored low- cost juices such as banana juice is in great demand for blending purpose. Banana juice when blended with other fruit juices imparts its undesirable color and flavor. Hence there is need to develop the decoloring and deflavoring system for banana juice.

Different fruit juices have different hue, color, haze and opacity. The information available on clarified banana fruit juice decoloration is limited. Very few or no publications on decoloration of clarified banana fruit juice are available. The research work on decoloration of clarified banana juice was considered essential for its commercial exploitation. Keeping above facts view, an attempt to develop a comprehensive technology for the decoloration of clarified banana juice using color adsorbents. A systematic research study was undertaken to decolor the clarified banana juice the specific objectives as:

1. To study different decoloration systems for clarified banana fruit juice.
2. To develop a decoloring system for clarified banana fruit juice.
3. To standardize the process protocol for decoloration of clarified banana fruit juice.

Experiments were planned and conducted to evaluate couple of adsorbents to decolor the clarified banana juice. Different conditions of adsorption along with variable dosage of adsorbents were attempted to evaluate their influence on the degree of decoloration and other bio-chemical quality parameters of the treated banana juice.

CHAPTER II

REVIEW OF LITERATURE

This chapter illustrates the published literature related with this study. The review covers the general information on nutritional benefits of banana, juice extraction, clarification and the decoloration studies of banana and similar other juices.

2.1 Nutritional Benefits of Banana

Wang *et al.* (1996) examined the antioxidative potency in several fruits and fruit juices and reported that banana had a medium antioxidative potency among these fruits. It was also revealed that banana contained a strong antioxidant, dopamine, in large quantity 2.5 – 10 mg per 100g of pulp and ascorbic acid at a considerable level. The antioxidative potency of dopamine was greater than that of flavonoids, glutathione, and catechin, and similar to that of the strong antioxidants gallocatechin, gallate and ascorbic acid. Banana is therefore one of the best sources of antioxidants.

Guylene *et al.* (2009) reported that bananas are used in special diets where ease of digestibility, low fat, minerals and vitamin content are required e.g. babies, the elderly and patients with stomach problems, gout, and arthritis. Green bananas possess antidiarrheal action. It is traditionally used to cure intestinal disorders. Banana peel is considered to be a functional food source against cancer and heart disease, since the banana peel is rich in gallocatechin.

2.2 Extraction of Banana Juice

Munyanganizi and Coppens (1976) studied two banana juice extraction methods from dessert and wine banana variety by pectolytic enzyme treatment (Rapidase C10) and by the CaO-S process and reported that yields of juice were 88 % for the enzymic and 82 % for the CaO-S process, irrespective of variety. Best results in the enzymic process were obtained by maceration at 50 °C, pH 4.2 - 4.3 and 0.05 % enzyme. Extraction yields increased with time to the maximum at 1-1 1/2 h, with fall in pH and viscosity. Both processes could be used with peeled or unpeeled bananas. The enzyme-extracted juice from peeled bananas was brown to dark -brown; the juice from dessert variety being subject to more rapid browning than that from the wine variety CaO-S extracted juice was pale yellow with no difference between variety in either colour or taste. Juice from unpeeled bananas was light brown (CaO-S) or dark brown (enzyme extraction) and had less flavour than that from peeled fruit. The viscosity of all juices was 2-3 cp at 20 °C.

Viquez *et al*. (1981) conducted a study on production of clarified banana juice using pectinolytic enzymes and reported clear juice recovery of 55 - 60 % (based on pulp weight used) from pulp incubated at 45 °C for 1 h with 0.01 % w/w of enzyme and by subsequent centrifugation at 2900 maximal relative centrifugal force for 20 min. Untreated pulp yielded less than 5 % of juice under these conditions. Hydraulic pressing of the pulp at 16 kg/cm^2 gives similar juice yields to those obtained by centrifugation.

Kyamuhangire *et al*. (2002) compared the yield, characteristics and composition of banana juice extracted by the enzymatic and mechanical methods. In the enzymatic extraction process, macerated ripe banana pulp was incubated with a commercial enzyme preparation (Pectinex Ultra SP-L) at 50 °C for 2 h. In the mechanical extraction process the ripe banana pulp was mixed with stretched strips of polythene and worked with a dough mixer at room temperature for 20 min until the juice appeared. It was reported that higher pure juice yield (604 g kg^{-1} pulp) was obtained with the enzymatic method than with the mechanical method (541 g kg^{-1} pulp). It was reported that adding water to the spent pulp from the mechanical process and extracting dilute juice improved the juice yield to 757 g kg^{-1} pulp. The enzyme-extracted juice had significantly higher soluble solids, titratable acidity, fructose, glucose, total nitrogen, density and mineral potassium whereas the mechanically extracted juice had significantly higher sucrose, pH and viscosity. It was also reported that the mechanical extraction process suffers from occasional juice extraction failures, it offers an opportunity to extract banana juice without excessive energy expenditure, and the juice produced is wholesome with a superior flavour to that produced by the enzymatic method.

Lee *et al*. (2006b) extracted banana juice using hot water extraction method at different extraction temperatures (35 – 95 °C) and times (30 – 120 min). The effects of the extraction conditions on juice yield, total soluble solids (°Brix), banana odour and taste were studied. An increase in extraction time and temperature of hot water extraction resulted in increase in juice yield, total soluble solids, banana odour and taste of the banana extract. Optimum conditions reported for hot water extraction of banana juice were 95 °C for 120 min.

2.3 Clarification of Banana Juice

Yu *et al.* (1987) studied the clarified banana juice production using pectinolytic enzymes. They had tested 5 commercial enzyme preparations on pulps of banana with colour index grade 7. It was observed that Rohapect D5L was more effective than the others. Average clear juice yield of 69.2 % (based on pulp wt.) was obtained from pulp treated at 45 °C for 2 h with 0.05 % (w/w) of Rohapect D5L. The optimal conditions with respect to enzyme concentration, incubation temperature, time and pH for Rohapect D5L were 0.01 %, 45 °C, 2 h and 5.0, respectively. The most acceptable (colour, aroma, taste) pH of banana juice was 4.2. Treatment of dipping banana pulp in 1.25 % NaHSO3 solution prior to juice extraction could improve juice discoloration and effect on juice yield was little.

Chen and Lin (1997) studied the application of enzyme preparation in clarification of banana juice. The enzymes were used to improve the yield and to clarify banana juice. Amylase was added at 0.2-0.6 % to fruit puree and pectase was added at 0.005-0.025 % to juice. It was reported that in terms of juice yield, optimum amylase treatment was at a concentration of 0.4 % at 55 °C for 30 min. It was observed that during clarification studies, highest transparency (90.5 % vs. 6.8 % in controls without pectase) was obtained using 0.015 % pectase at 45 °C for 60 min.

Lee *et al.* (2006a) optimized conditions for enzymatic clarification of banana juice using response surface methodology (RSM). Banana juice was treated with pectinase at various enzyme concentrations (0.01–0.1 %), temperatures (30–50 °C) and times (30–120 min) of treatment. The process variables for best combination of response function were enzyme concentration 0.084 %, temperature 43.2 °C, and incubation time 80 min. The filterability (0.073 s^{-1}), clarity (0.006 Abs), turbidity (0.92 NTU) and viscosity (1.89 cps) were observed.

2.4 Decoloration using Ion Exchange Resins

Vural and Arda (2002) conducted equilibrium and kinetic studies on the adsorption of dark colored compounds from apple juice using adsorbent resin at different adsorbent resin concentrations (1, 2, 4, 8 g adsorbent resin per liter of apple juice) and temperatures (20–80 °C). It was observed that the initial equilibrium time of adsorption was about 2 h at 20 °C for all concentrations of adsorbent resin and decreased with adsorption temperature increases. Increasing the adsorbent resin concentration from 1 to 4 g/l juice also increased the efficiency of adsorption, while no remarkable increase was noted afterward. It was reported that for an adsorbent concentration of 4 g/l apple juice, an adsorbent resin–apple juice contact time of 2 h with a temperature from 40 to 60 °C is enough to improve the color of apple juice up to 40–60 % for a practical application.

Achaerandio *et al.* (2002) studied the vinegar decoloring by adsorption with exchange resins and the decoloring capacity of three commercial resins as adsorbent material was evaluated. They compared the decoloring capacity of the selected resin (Lewatit S-6328-A) with a powder activated carbon and found that for a batch process with white and rose vinegars with resin Lewatit S-6328-A (10 g/l for white and 20 g/l for rose) at equilibrium, the maximum decolorization efficiency was 69 % and 72 %, respectively. The adsorption of colored compounds with exchange resins in continuous packed columns seems to be technically feasible. The decoloring efficiency of the resin was slightly lower than that of the activated carbon which means that more resin was required for the same decolorization efficiency as compared to activated carbon.

Nongxue *et al*. (2007) conducted a study upon kinetic process of apple juice adsorption de-colorationby using different temperatures (25–70°C) and resin concentrations (1, 2, 8 g/l). All the conical flasks were put into water bath with fixed temperatures and shaken once at an interval of 30 min. In the adsorption process, absorbance values of 420 nm were measured at the time intervals of 0, 15, 30, 45, 60, 180, 360, 540, 720, 1260, and 1440 min. All the samples were filtered via Syringe Filter with 0.45 µm membrane. It was reported that within the range of resin concentration of 2–4 g/l, adsorption effect was apparently significant. At 70 °C and 55 °C, the coverage rate for resin reaching the initial equilibrium was higher. The real temperature for apple juice via ultrafiltration, the suitable temperature and resin concentration for using adsorption resin to carry out apple juice adsorption de-coloration were 55 °C and 2–4 g/l, respectively.

Ibarz *et al*. (2008) investigated the effect of adsorbent resin upon kinetic process of peach juice adsorption de-coloration at different temperatures (10 °C to 50 °C) and the concentration of resin in the juice (0.01 to 0.2 g resin/g juice). The samples were filtered through 0.45 µm membrane. Finally, the absorbance was measured at 420 nm in order to obtain a measure of the melanoidins remaining in the juice. It was observed that the absorption efficiency tends to increase with the rise in temperature and the amount of resin used. The best results were obtained at 30 °C with a 0.02 g resin/g juice ratio.

2.5. Decoloration using Bentonite

Bruce (1988) studied the bentonite fining of juice and wine. He found that bentonite affect red wine color directly by binding with positively-charged anthocyanins, which results in up to 15 % color removal. He observed that bentonite color removal is dependent upon the temperature and age of the wine. Bentonite removed more color from younger wines than gelatin. This was due largely to the greater action of bentonite on colloidal color material found in younger wines.

Lee *et al.* (2007) investigated the effects of fining treatment and storage temperature on the quality of clarified banana juice. It was noted that changes were significantly greater in control juice stored at higher temperature than in juice stored at 4 or 25 °C up to 6 months. Sensory evaluation revealed that juices treated with bentonite or a combination of gelatin and bentonite and stored at 4, 25 or 37 °C were acceptable up to 6 months, whereas untreated juice stored at 37 °C was only acceptable up to 16 weeks. A significant decrease in turbidity was observed for the juice treated with bentonite and a combination of gelatin and bentonite from 29.63 NTU to 16.15 NTU and 21.96 NTU, respectively. The rate of haze formation increased slightly at lower storage temperature

(4 °C), and more dramatically at 37 °C. Haze formation and browning were enhanced by higher storage temperature. Therefore, storage temperature recommended for enhancing stability of product, which prevents haze formation, was 4 °C.

2.6. Decoloration using Benzoyl Peroxide and Hydrogen Peroxide

Mcdonough *et al.* (1967) studied the decolorization of annatto in cheddar cheese whey and described the simple and effective method of decolorizing annatto-containing cheddar cheese whey before drying. Annatto was easily decolorized by oxidation by both benzoyl peroxide and hydrogen peroxide. While several combinations of peroxides and heat were acceptable, 0.002 % (w/v) benzoyl peroxide added to whey with holding at 60-63 °C for 1 h gave good results. All traces of oxidized flavor disappeared during the pilot plant concentration and spray-drying process. Oxidation with bleaching agents appears to be an efficient and satisfactory means of decolorizing annatto coloring in cheese whey. The process is relatively simple and can be used to obtain non colored dried whey for use in foods but the oxidized flavor intensities in the whey immediately after treatment with benzoyl peroxide were generally strong.

2.7. Decoloration using Vacuum Filtration

Regling *et al.* (1981) studied the decoloring of pink grapefruit juice using vacuum filtration. It was found that pink grapefruit juice or concentrate was decolorized using vacuum filtration through the bed of coarse diatomaceous earth particles at pressure differential from 10-25 inches of mercury and at the flow rate from 0.1-0.5 gal/lit/sq.ft to form a product suitable for beverage use or blending with white grape juice.

2.8. Decoloration using Membrane Processing

Carrin *et al.* (2007) carried out decoloration of browned apple and grape juice by physical separation of melanoidins with combined use of ultrafiltration (UF) and nanofiltration (NF) membranes. Concentrated samples of apple and grape juices were stored at relatively high temperature (53 °C) until considerable browning level was obtained. Decoloration of browned juices by ultra (UF) and nanofiltration (NF) were performed with a cross-flow membrane filtration unit, using thin-film composite based in polyamide membranes, with cutoff in the range of 150-450 Da; and cellulose acetate or polyvinylidene fluoride membranes, in the range of 2-30 kDa. It was observed that after filtration with NF membranes (Cutoff < 2,000 Da); browned apple juice color was reduced to a level close to that of a fresh clarified juice. Although changes in pH of permeates were not observed, reduction in °Brix occurred after nanofiltration. Contrarily, color recovering by NF resulted unviable for highly colored grape juices and traditional active carbon descoloration should be used.

2.9. Decoloration using Activated Charcoal by Adsorption

Activated charcoal is a charcoal that has been treated with oxygen to open up millions of tiny pores between the carbon atoms. The use of special manufacturing techniques results in highly porous charcoal that has surface areas of 300-2000 square meters per gram. These so called active or activated charcoal are widely used to adsorb odorous or coloured substances from gases or liquids. When a material adsorbs something it attaches to it by chemical attraction. The huge surface area of activated charcoal gives it countless bonding sites. When certain chemicals pass next to the carbon surface they attach to the surface and are trapped. Activated charcoal is good at trapping other carbon-based impurities (organic chemicals). The amount of material removed depends on the capacity of the activated carbon (activated charcoal) as well as the affinity of the material for the charcoal was studied by Azeez (2005).

Adsorption is a separation process in which certain components of a fluid phase are transferred to the surface of a solid adsorbent. Most adsorbents are highly porous materials and adsorption takes place primary on the walls of the pores or at specific sites inside the particle. Adsorption is commonly used to purify contaminated fluids that are unacceptable in smell and taste. Its main applications in the vapor phase are recovery of organic solvents, separation of air contaminants, and gas drying; those associated with the liquid phase are separation of water contaminants, removal of colored impurities from sugar solutions, and impurities from vegetable oils. Additional liquid phase applications were related to pharmaceutical needs and those involving the improvement of fruit juices and their derivatives (i.e., debittering of citrus and grape juices and their derivatives, color control and stability, removal of undesirable aromatic and taste components, deionization and demineralization). Typical adsorbents include activated carbon, natural and synthetic zeolites (molecular sieves), clays, ion exchange resins, silica gel, activated alumina, gelatine/bentonite, casein, ion-exchange waxes and polyvinyl polypyrrolidone (PVPP) had been used for the removal of polyphenols from fruit juices as reported by Giovanelli and Ravasini (1993); Carbasa *et al.* (1998).

Decolourization simply means colour removal. The chemical nature of activated charcoal combined with a high surface area and porosity, makes it an ideal medium for the adsorption of organic chemicals. The most widely used of these decolourizing agents was the activated charcoal due to its economic advantages over others, its availability and its chemical inertness towards most of our materials of construction. The chloro-compounds on the other hand were usually corrosive, causes damage and interfere with chemical composition of the product, where they are available they are often found to be costly (Azeez , 2005).

Carbasa *et al.* (1998) investigated the adsorption treatments using different activated carbon for browned clarified peach juice. It was found that contact time of 10-15 min was enough to obtain suitable juice, the optimum temperature was found in between 30-50 °C and most effective granular activated charcoal particle size 2-4 mm. Improvements of the juice color due to the adsorption treatments were detected by a decrease in the absorbance at 420 nm and in the HMF content. Also, it was observed that the pH increased and the soluble solids decreased as the concentration of activated charcoal increased.

Arslanoglu *et al.* (2005) conducted research on the adsorption of dark colored compounds from peach pulp on granular activated carbon (GAC) at different GAC concentrations (0.5, 1, 3, 5 kg GAC per m^3 peach pulp) and the temperature range of 20–60 °C. The equilibrium isotherm for each dark colored compounds-GAC system was determined and absorbance data at 420 nm were used to plot all the isotherms. It was found that initially, the rate of adsorption of dark colored compounds onto granular activated carbon was very high. This was then followed by a slower rate, and gradually approached a plateau and the adsorption efficiency of dark colored compounds increased with increase in granular activated carbon dosage and temperature. An adsorbate concentration of 3 kg PAC/m^3 pulp and PAC-peach pulp contact time of 30 min for all temperatures studied is enough to improve the color of peach pulp for a practical application.

Soto *et al.* (2008) conducted a study on charcoal adsorption of phenolic compounds present in distilled grape pomace. It was observed that adsorption kinetics followed a pseudo- second order rate, and equilibrium was reached in less than 15 h. It was also observed that charcoal adsorption of phenolic compounds with antioxidant activity present in grape pomace was feasible and can be performed efficiently.

David and Palmquist (2009) conducted a study on decolorization/deodorization of zein via activated carbons and molecular sieves. A batch process was used to evaluate each of five different activated carbons and zeolites to determine the adsorption characteristics of protein and the color and off-odor components. It was observed that processing zein aqueous ethanol solutions at 55 ºC enhanced the adsorptions of the off-odor and color components of zein relative to the adsorption of protein for both the activated carbon media and zeolites resins.

CHAPTER III

MATERIALS AND METHODS

This chapter explains the experimental set-up including experimental procedures and various methods adopted for the study of decoloration of clarified banana juice. The details of biochemical analysis are also explained.

3.1. Raw Material

3.1.1 Banana juice

The clarified banana juice (CBJ) of 15 °Brix was prepared by diluting Clarified Banana Juice Concentrate using distilled water. The clarified banana juice concentrate (Fig 3.1) was procured from M/s Jain Food Park, Jalgaon. Clarified banana juice concentrate had 65-66 °Brix, acidity of 1.20 – 2.40 %, pH of 3.5 – 4.5, and turbidity of 50 NTU at 20 ° Brix. This brix was adjusted by adding the calculated amount of distilled water.

The L, a, b values measured using colorflex (Model CXI55) spectrocolorimeter for clarified banana juice so obtained were 55.38 ± 1.45, 3.44 ± 1.78, 27.31 ± 1.02 respectively; total soluble solids 15.0 ± 1 °Brix; turbidity 22 ± 2 NTU; titratable acidity as citric acid 0.19 ± 0.04 percent and pH was 3.5 ± 0.02. The clarified banana juice contained total sugars, reducing and non- reducing sugars as: 14.02 ± 0.16, 8.25 ± 0.11 and 5.77 ± 0.05 percent, respectively.

3.1.2 Bentonite

Bentonite is a complex hydrated aluminum silicate with exchangeable cationic components: (Al, Fe, Mg) Si_4O_{10} $(OH)_2$ (Na+, Ca++). The most commonly used form is sodium bentonite. Sodium bentonite has enhanced protein binding ability and adsorbing capacity over calcium bentonite. One kg bentonite (light gray to off-white) (Fig 3.2) of particle size 300 mesh (46 microns) and moisture content of 11 % was procured from M/s Jain Food Park, Jalgaon.

Fig 3.1 Clarified banana juice concentrate (left) and clarified banana juice (right)

Fig 3.2 Bentonite

3.1.3 Activated charcoal

Charcoal, excellent adsorbent is widely used in the treatment of solution for removal of coloring matter by adsorption. Activated charcoal is a charcoal that has been treated with oxygen to open up millions of tiny pores between the carbon atoms. One kg powdered activated charcoal (PAC) of particle size 300 mesh (46 microns) and moisture content of 5.0 % was procured from Laboratory Rasayan S. D. Fine- Chem. Ltd, Mumbai (Fig 3.3). The PAC was packed in cardboard box, inner lined with HDPE and stored at 26 $\pm$ 1 °C under dry condition. At the time of use, the PAC was taken on tarred butter paper with the help of plastic spoon and mixed directly in the CBJ.

. **Fig 3.3 Powdered activated charcoal**

3.2 Decoloration of Clarified Banana Juice

The clarified banana juice samples (100 g) with 15 °Brix was prepared from the original clarified banana juice (CBJ) concentrate of 65 - 66 °Brix by diluting it with distilled water. The samples were placed in constant temperature water bath (Hexatec Model: HIPL 010H GMP Model) for maintaining the required temperature and then adsorbents were added. At the end of pre determined adsorption duration, the sample was filtered through vacuum membrane filter (0.45μm). Figure 3.4 depicts the process flow chart for decoloration of CBJ used during all the experiments.

The sample of 100 g clarified banana juice of 15 °Brix was taken in 250 ml conical flask and flask was placed in the thermostatic water bath at pre-set temperature. A pre-calculated amount of adsorbent was accurately weighed. When the temperature of the juice reached to the desired level, the weighed amount of adsorbent was added to each flask.

Conical flasks were kept for decoloration for set time and were stirred intermittently. The samples were removed from the water bath at the end of 30 min and 60 min and were filtered through a 0.45μm membrane filter (Millipore) using vacuum pump (Make: Aruntak, Arun Engg. Works oilsealed type Model No- AV 575) prior to measurement of color value. After the treatment, the decolored samples were analyzed for further chemical analysis like color difference, TSS, turbidity, pH, etc.

The effect of four different factors viz. type of adsorbent, adsorbent concentration, adsorption temperature and adsorption duration on the quality of decolored clarified banana juice was investigated. The details are given in experimental design later on in this chapter. Bentonite (0.3, 0.5, 0.7, 0.9, 0.9 g per 100 g of CBJ), PAC concentration (0.3, 0.5, 0.7, 0.9, 1.5, 2.0, 3.0, 4.0, 5.0, 7.0 and 9.0 g per 100g CBJ), adsorption temperature (30, 45, 60 °C) and adsorption duration (30 and 60 min) were varied as above. Various observations as mentioned in para 3.4 were recorded using the standard procedures. The influences of the above variables on color value, TSS, pH, turbidity, etc. of the final product were evaluated. The decoloring parameters were optimized based on the maximum color difference of the decolored juice sample.

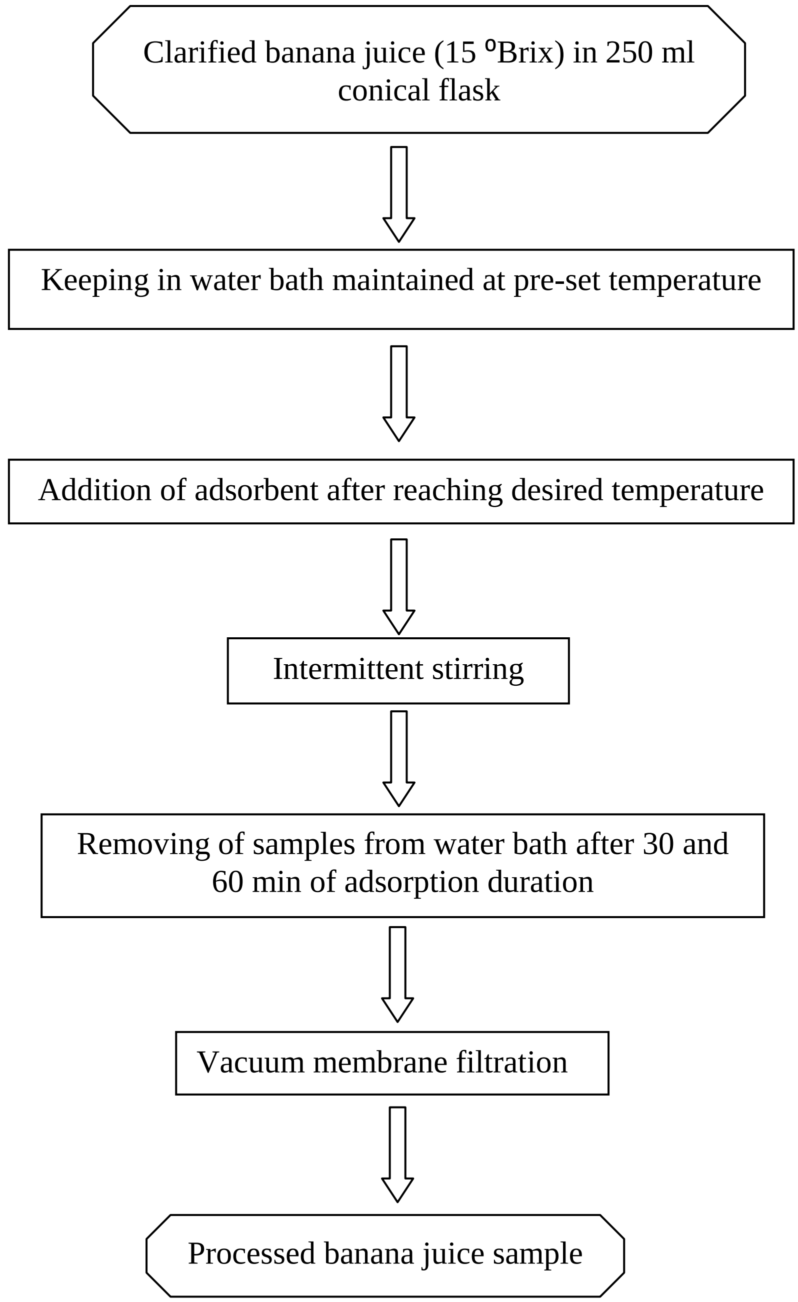


Fig 3.4 Process flow chart for decoloration of clarified banana juice

3.3 Analytical Methods

The original CBJ sample and the optimized decolorized CBJ were analyzed for color value, TSS, pH, turbidity, total sugars, reducing sugars, non reducing sugars, ascorbic acid and titrable acidity. The samples after each treatment were analyzed for color value, TSS, pH and turbidity.

3.3.1 Estimation of color value

The color of CBJ and the treated banana juice was determined using a Colorflex (Model CXI55) spectrocolorimeter (Fig. 3.5), equipped with the light source D_{45} and observation angle of 0 °, utilizing the Hunter Lab system, with direct reading of the L (luminosity), a (red intensity) and b (yellow intensity) values. The colorflex system consisted of color flex optical sensor and IBM compatible computer composed of system unit, monitor, keyboard and mouse. The spectrocolorimeter used for color measurement is shown in .

The colorimeter was calibrated against standard black and white tile prior to the actual experiments. Hunter Lab had developed a "Ring and Disk" assembly to measure the translucent food. A 10 mm black ring is inserted into the 62.5 mm glass sample cup. The cup was then filled with sample. A white ceramic disk was then pushed down through the sample until it rests on top of the black ring which had given a constant light path and white background. The cup with sample was then placed on the instrument port for measurement. The sample cup opaque cover provided a light trap to exclude the interference of external light on the sample contained in the sample cup (Sandi D *et al.*, 2004). DE values, a measure of the total color difference, were calculated using the following relation:

$$DE = \sqrt{DL^2 + Da^2 + Db^2} \quad \ldots\ldots (3.1)$$

where, DL, Da, Db represent the deviations of the individual values from the respective values from a fresh clarified banana juice (L = 55.38 , a = 3.44 , b = 27.31). DE denotes greater color change from the reference material. Higher DE value means more decoloration i.e. better quality or desired product.

3.3.2 Estimation of total soluble solids

The total soluble solids present in fresh clarified banana juice and treated banana juice was determined using two different digital refractometers (Make: Atago Ltd, Japan), (Fig 3.6) having a range from 0 - 45 °Brix and 45 - 90 °Brix.

3.3.3 Estimation of pH value

The pH value of fresh clarified banana juice and treated banana juice sample was determined using a digital pH meter *ELICO*, Model- LI 610; Microprocessor based pH system as shown in Fig 3.7. The pH meter was standardized with double distilled water of 7.0 pH and standard buffer solution of 4.0 and 9.1 pH before analysis

3.3.4 Estimation of turbidity

The turbidity of the juice was determined using a portable Turbidimeter (Fig 3.8) (Model 2100P, Hach Company, Loveland, CO, USA) and was reported as Nephelometric Turbidity Units (NTU) (Lee *et al*., 2007). Fresh clarified banana juice and treated banana juice samples were placed in a cell holder for turbidity measurements. Samples were shaken by gently rocking the sample holder before the measurements were taken. Minimum the turbidity better the quality of the product.

3.3.5 Estimation of total sugar

For total sugar estimation, Lane and Eynon method (Ranganna, 1986) was used. Five ml of clarified banana juice was taken in a 250 ml conical flask and 50 ml distilled water added to it. About 5 g of citric acid was then added and boiled for 10 minutes for the inversion of sugar. The resulting solution was then neutralized with 1 N NaOH solution using phenolphthalein as the indicator. The chemical used for the titration was a mixture of Fehling solution A & B. This solution was titrated against the sample solution and the amount of total invert sugar present in 100 ml of juice was estimated as per the procedure described by Ranganna (1986).

$$Total\ sugar,\ (\%) = \frac{mg\ of\ invert\ sugar \times dilution \times 100}{titre \times volume\ of\ sample \times 1000} \qquad \ldots (3.2)$$

Fig 3.5 Colorflex spectrocolorimeter

(a) range (0 – 45 °Brix) **(b) range (45 – 90 °Brix)**

Fig 3.6 Digital refractometers

Fig 3.7 pH meter

Fig 3.8 Turbidimeter

3.3.6 Estimation of reducing sugar

Reducing sugar of CBJ was determined as per the Lane and Eynon method (Ranganna, 1986). Five ml of clarified banana juice was transferred in to a 250 ml flask. About 100 ml of distilled water was added and solution was neutralized with 1 N NaOH solution using phenolphthalein as the indicator. Two milliliter of lead acetate solution was added to the flask and shaken. It was made to stand for 10 min. Necessary amount of potassium oxalate solution was then added to remove the excess lead present in the sample. The solution was then made up to 250 ml using distilled water, filtered and used for the estimation of total reducing sugar.

A solution containing equal volume of Fehling reagents A & B was titrated against the sample solution and the amount of reducing sugar present in 100 ml of juice was estimated as per the procedure described by Ranganna (1986).

3.3.7 Estimation of non reducing sugar

The amount of non reducing sugar present in the clarified banana juice was calculated using equation (3.3).

$$Non\ reducing\ sugar, (\%) = [Total\ sugar, (\%) - reducing\ sugar, (\%)] \quad \ldots (3.3)$$

3.3.8 Estimation of total ascorbic acid

Estimation of ascorbic acid was carried out as per the procedure mentioned in Ranganna (1986). Five ml of the standard ascorbic acid solution was pippeted out into 100 ml conical flask and 5 ml of 3 % HPO_3 solution was added. Dye solution was filled in microburette. Ascorbic acid solution was titrated with the dye solution to a pink color, which should persist for 15 sec. Titre was noted as mg of ascorbic acid per ml of the dye and the dye factor was calculated using equation (3.4).

$$dye\ factor = \frac{0.5}{Titre} = \frac{0.5}{V} = mg\ ascorbic\ acid\ per\ ml\ dye \quad \ldots\ldots (3.4)$$

where, V= volume of dye solution required (titre)

Further, 10 - 20 ml sample was blended with 3 % HPO_3 solution and made up to 100 ml and filtered through Whatman No. 1 filter paper. Sample extract (2-10 ml) was taken in a 100 ml conical flask and titrated against the dye solution. Volume of the sample should be such that the titer value falls in the range of 3-5 ml. Then the ascorbic acid content was computed using equation (3.5)

$$Ascorbic\ acid\ content\ \left(\frac{mg}{100g}\right) = \frac{dye\ factor \times V_2 \times 100 \times 100}{V_1 \times V_3} \qquad \text{...... (3.5)}$$

Where, V_1 = Volume of sample extract taken for dye titration, ml

V_2 = Volume of dye required (titre), ml

V_3 = Volume of the sample taken for extraction with HPO_3, ml

3.3.9 Estimation of titrable acidity

Acidity of fresh clarified banana juice was measured and expressed as amount of anhydrous citric acid present in 100 ml of clarified banana juice. 10 ml of the sample was transferred to 250 ml conical flask. It was then diluted with distilled water and the volume was made up to 100 ml. Few drops of phenolphthalein indicator were added to it and titrated against 0.1 N NaOH till the color of solution turn into pale pink (Ranganna, 1986). The equation used for the calculation of titrable acidity is the following

$$Titrable\ acidity,\ \% = \frac{T \times N \times V \times E}{W_s \times V_s \times 1000} \times 100 \qquad \text{..... (3.6)}$$

Where,

T = titre value, ml

N = normality of alkali solution

V = volume made up, ml

E = equivalent weight of acid, g

W_s = weight of sample, g

V_s = volume of sample taken for titration, ml

3.4 Experimental Plan

Variables

1) Clarified fruit juice
   a. Banana
2) Adsorbents
   2.1 Concentration of powdered activated charcoal (g per 100 g juice)

a. 0.0	g. 2.0
b. 0.3	h. 3.0
c. 0.5	i. 4.0
d. 0.7	j. 5.0
e. 0.9	k. 7.0
f. 1.5	l. 9.0

   2.2 Concentration of bentonite (g per 100 g juice)
   a. 0.0
   b. 0.3
   c. 0.5
   d. 0.7
   e. 0.9
3) Temperature of juice (°C)
   a. 30
   b. 45
   c. 60
4) Adsorption duration (min)
   a. 30
   b. 60

Observations

a. Color value	f. Reducing sugars
b. Total soluble solids	g. Non- reducing sugars
c. pH	h. Ascorbic acid
d. Turbidity	i. Titrable acidity
e. Total sugars	

Duration of actual study: 6 months

Statistical design: Completely Randomized Design

Replication: Two

Location: Jain Hills**,** Jain Irrigation Systems Ltd, Jalgaon.

3.5 Sensory Evaluation

The treated/processed samples were evaluated for sensory parameters such as appearance, colour, taste, flavour and overall acceptability by trained panel using 9 point hedonic scale. Samples were evaluated in individual sensory booths under cool white fluorescent light and presented to the panelists in a random order in colourless, transparent glasses. The samples were served to the panelists in a random order. The panelists were instructed to cleanse their palates between samples using water (Ranganna, 1986).

3.6 Statistical Design

All experiments were conducted in required number of replications for statistical analysis and the data were subjected to analysis using Complete Randomized Design (CRD) as per the procedure given by Steel and Torrie (1980) and using analysis of variance (ANOVA). Differences were identified as significant or non-significant based on mean squares and F-test for significance at level 5 % of each treatment.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the results and discussion of the experiment entitled **"Appraisal of Different Decoloration Systems for Clarified Banana Fruit Juice."** The decoloration of clarified banana juice was attempted using different adsorbents and adsorption conditions. The amount of adsorbent required, the temperature and duration for adsorption to decolor the clarified banana juice and the effect of degree of decoloration on clarified banana juice was evaluated within the scope of this study. The decoloring parameters were optimized for the maximum color value of the final product within thw range of the parameters studied. The effect of decoloration on quality of final product has also been covered.

Decoloration was carried out using two different adsorbents namely bentonite and activated charcoal. The different concentrations at different adsorption temperatures and for variable adsorption duration were used to observe the decoloring effect on the clarified banana juice. The effect of different adsorbents on color value and different parameters of the treated banana juice is discussed below.

For effective blending of juices without imparting the characteristic color, a minimum color value of about 28.00 was considered as needed in the CBJ, to make it suitable candidate for blending. Color value lower than 28.00 for the treated juice perhaps shall not be classified as decolored juice. These observations were made physically during the experiments and other feasibility trials. To achieve the required decoloration in the CBJ, the treatments are explained below.

Similarly, the turbidity of the juice should be as low as possible for decolored juice to be used for blending. However, getting turbidity level to zero may not be possible by use of adsorbent. Hence, the treatment combinations giving the turbidity value as close to zero, are considered to be effective.

4.1 Effect of Bentonite on Degree of Decoloration of Clarified Banana Juice

Though the combination concentration of bentonite adsorption temperature and duration of treatment caused decoloration of CBJ, there was no specific trend observed (Table 4.1).

As the bentonite concentration was increased from 0.3 - 0.9 %, the largest color value observed was only 11.29 which were at 0.7 % bentonite concentration for treatment combination of 60 °C for 60 min. In general, an increase in concentration levels of bentonite from 0.3 to 0.7 %, the color value increased for both the periods (30 and 60 min) and temperatures (30, 45 and 60 °C) of treatment. But, further increase in concentration beyond 0.7 %, caused reduction in color value of the CBJ for almost all the temperatures and times of bentonite treatment (Figs 4.1a and 4.1b).

The turbidity of the CBJ improved/ decreased to some extent on increasing the concentration of bentonite for the temperature and time range tested (Figs 4.2a and 4.2b). It was clearly observed that by bentonite treatment, the turbidity of the CBJ was reduced at very low level. The maximum decrease in the turbidity was 0.76 NTU at 0.9 % bentonite concentration at adsorption temperature at 30 °C for 30 min adsorption duration.

It can also be seen that the difference in the turbidity was very narrow when the adsorption duration was increased from 30 to 60 min corresponding to all adsorption temperature and bentonite concentration. As such the adsorption duration had very little effect on the turbidity of the treated juice with respect to the temperature as well as bentonite concentrations. Further, the bentonite treatment had negligible effect on the other chemical parameters of the CBJ such as pH, total soluble solids, etc. (Table 4.1).

Further, neither the increase in temperature nor in duration of treatment, caused better decoloration. In fact, no specific trend was obtained. Considering no specific trend for the influence of bentonite concentration for treatment, temperature and times tested, further investigation using bentonite was discontinued

Table 4.1 : Effect of bentonite on color value and quality of treated banana juice

Adsorbent	Concen-tration (%)	Adsorption Time (min)	Temp (°C)	Color values (DE)	TSS (°Brix)	Turbidity (NTU)	pH
Bentonite	0.3	30	30	6.11	15.0	1.10	3.50
			45	1.98	15.0	1.16	4.79
			60	3.02	15.0	1.22	3.66
		60	30	4.00	14.9	1.07	3.47
			45	0.93	15.0	1.17	4.69
			60	4.14	15.0	1.23	3.69
	0.5	30	30	4.86	15.0	0.91	3.66
			45	4.77	14.9	1.11	4.80
			60	4.46	14.9	1.15	3.79
		60	30	5.29	15.0	0.91	3.58
			45	2.14	14.9	1.12	4.68
			60	1.78	15.0	1.14	3.83
	0.7	30	30	5.57	15.0	0.86	3.89
			45	9.14	15.0	0.96	4.77
			60	10.74	15.0	0.97	3.97
		60	30	4.22	14.7	0.88	3.91
			45	2.41	14.8	0.97	4.67
			60	11.29	14.7	0.97	4.01
	0.9	30	30	3.94	14.9	0.73	4.10
			45	6.55	15.0	0.86	4.77
			60	3.91	15.0	0.85	4.36
		60	30	5.10	14.5	0.79	4.20
			45	4.33	14.6	0.85	4.67
			60	4.73	14.6	0.87	4.38

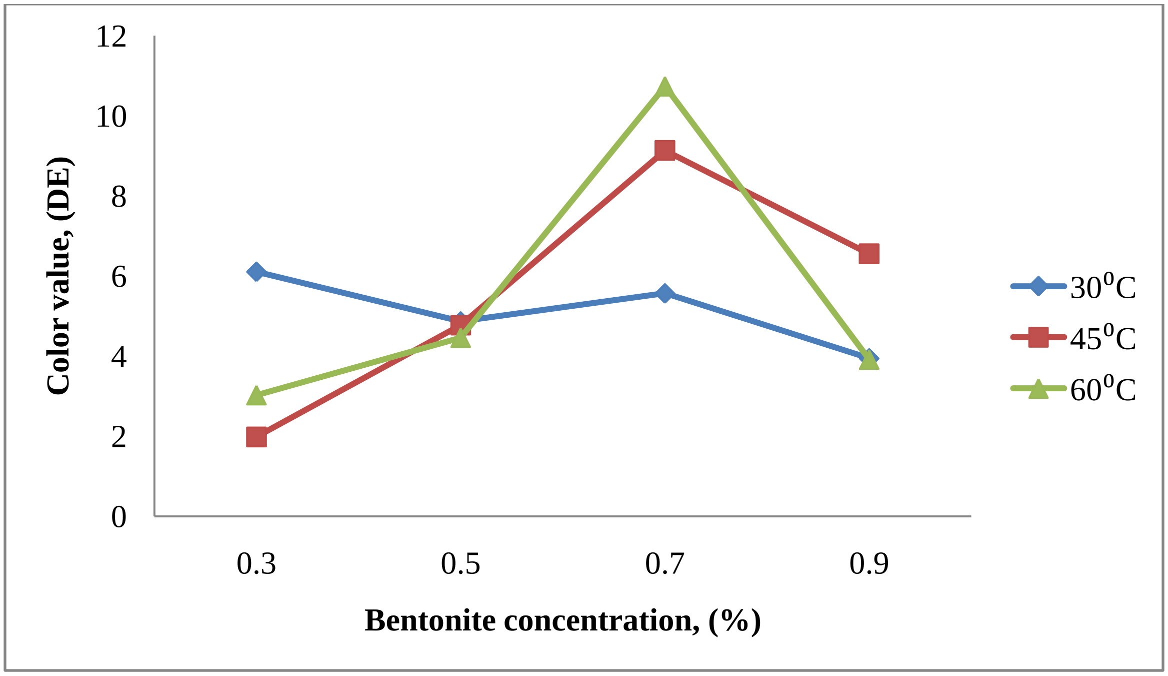


Fig 4.1a. Effect of bentonite concentration on the color value of treated juice for 30 min adsorption duration

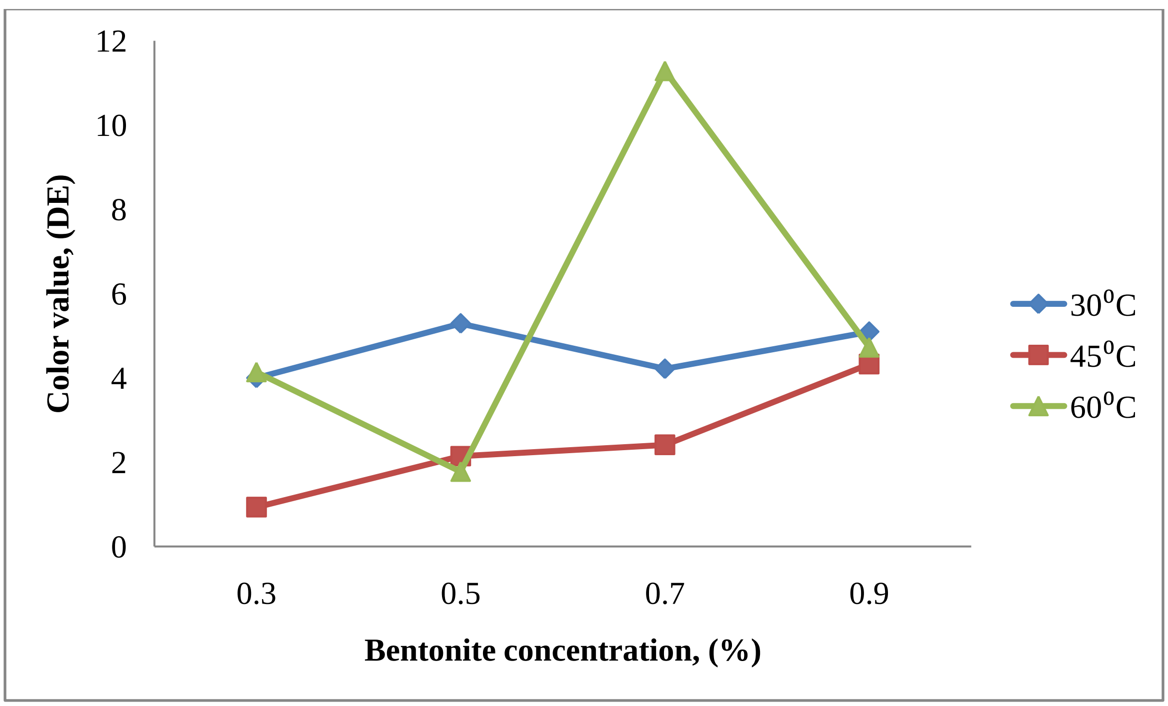


Fig 4.1b. Effect of bentonite concentration on the color value of treated juice for 60 min adsorption duration

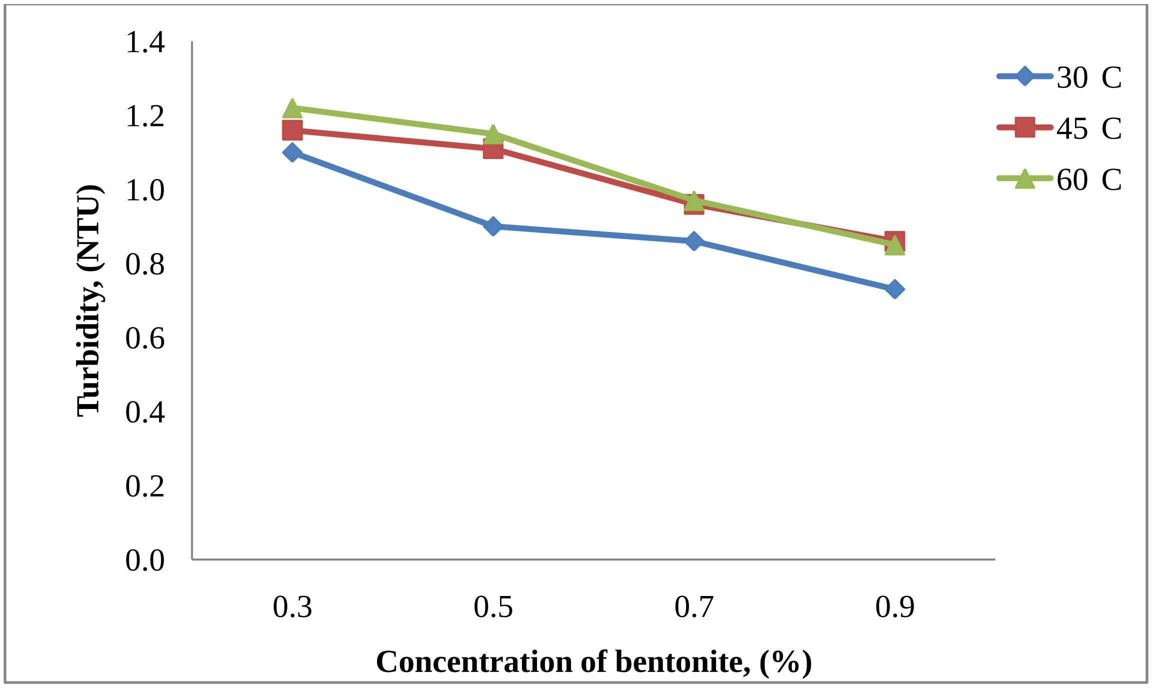


Fig 4.2a Effect of bentonite concentration on the turbidity of juice for 30 min adsorption duration

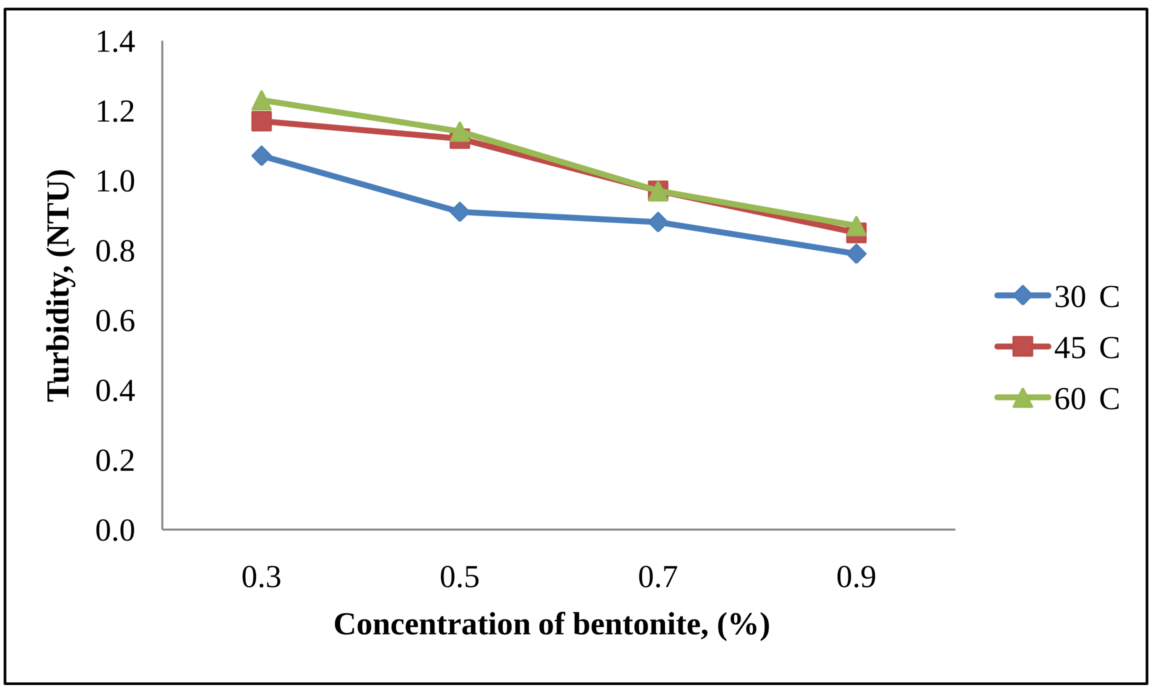


Fig 4.2b Effect of bentonite concentration on the turbidity of juice for 60 min adsorption duration.

4.2 Effect Of Powdered Activated Charcoal (PAC) on Degree of Decoloration of Clarified Banana Juice

It was clearly observed that the degree of decoloration (color value) improved for almost all the temperatures and adsorption durations with increase in the concentration of PAC (Table 4.2). However, no specific trend was observed with temperature for any given concentration of PAC and duration of treatment.

Table 4.2 : Effect of adsorption temperature, time and PAC concentration on color value (DE) of the decolored banana juice

PAC concentration (%)	Color value (DE) after treatment at different temperatures and time					
	30min			60min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	11.10	17.43	19.60	19.74	16.53	17.18
0.5	17.91	21.07	22.31	23.36	20.42	22.39
0.7	22.14	24.18	18.25	26.55	23.13	19.12
0.9	26.09	24.28	26.24	27.09	19.74	24.25
1.5	28.30	26.95	27.21	28.05	22.24	21.15
2.0	30.61	30.49	31.19	31.81	28.63	31.27
3.0	29.16	28.50	28.86	30.94	31.68	29.13
4.0	32.77	28.98	33.71	34.30	30.30	32.22
5.0	28.50	33.93	32.98	34.49	35.00	29.45
7.0	31.01	32.89	33.53	35.00	34.53	31.83
9.0	32.90	32.12	33.60	34.59	33.64	35.14

Variation in color value with PAC concentration and adsorption temperature-time combinations for all experiments is also shown graphically in Figs. 4.3a and 4.3b. The trend exhibits a non linear increase of color value with PAC concentration for almost all the temperatures and times of treatment.

The maximum color value was 35.14 when the PAC concentration was 9.0 % and the decoloring temperature was 60 °C and decoloring time was 60 min while the minimum color value was observed to be 16.53 at 45 °C adsorption temperature, 60 min adsorption duration for 0.3 % concentration of PAC. The degree of decoloration was slightly faster for the initial increase in the PAC concentration from 0.3 to about 1.5 - 2.0 % for many of the treatments. As the PAC concentration was further increased beyond 2.0 %, the graphs are relatively flat.

In fact, the color improvement continued with increase in PAC concentration but at slightly slower rate. It can also be seen that the difference in color value was very narrow when the PAC concentration was increased from 5.0 to 9.0 % corresponding to the 30 and 45 °C adsorption temperatures. The clear difference in the physical color among various samples is seen Fig 4.4 and 4.5 as affected by the PAC concentration and treatment temperature-time combination.

The increase in the color value with the increase in PAC concentration at the same adsorption temperature and duration might be due to the more possible surface area made available by PAC for adsorption. Kadirvelu *et al* (2000) also observed an increase in the percentage adsorption with increasing adsorbent dosage and was opined that the increase was due to the availability of more surface functional groups at higher carbon concentration.

The results also implied that as the concentration was increased there was increase in the color value due to the increased quantity of PAC which made more surface area available to adsorb the color pigments from the banana fruit juice. The similar results were observed by Gokmen and Serpen (2002) for adsorption of dark colored compounds from apple juice by using adsorbent resin.

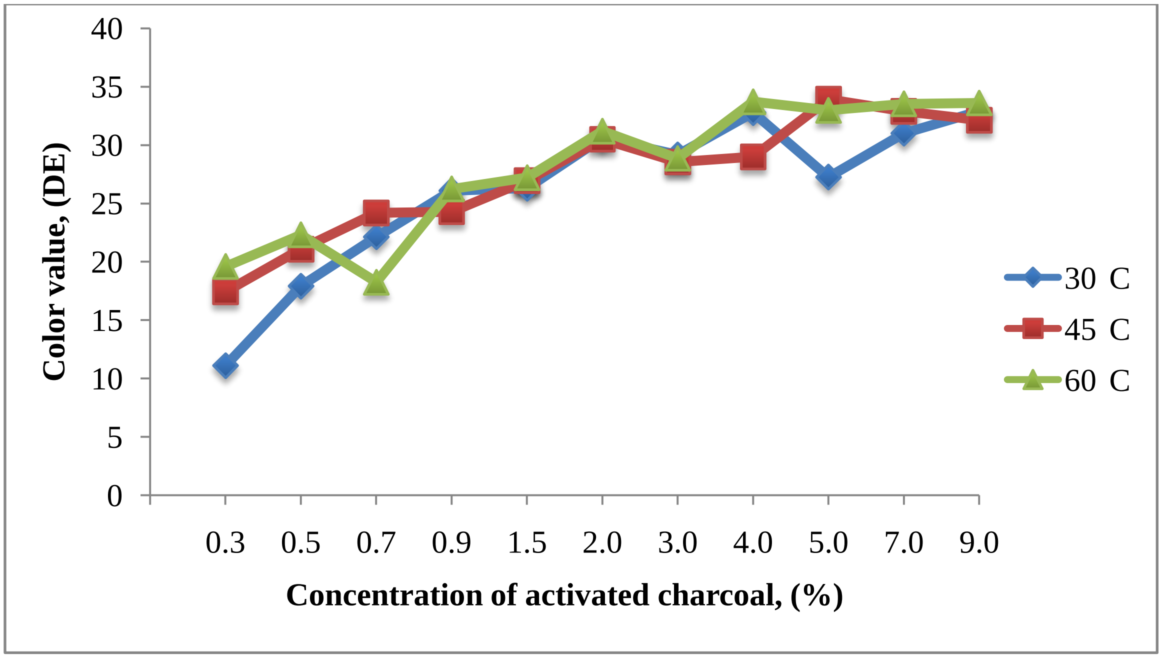


Fig 4.3a. Effect of activated charcoal concentration on the color values of juice for 30 min adsorption duration.

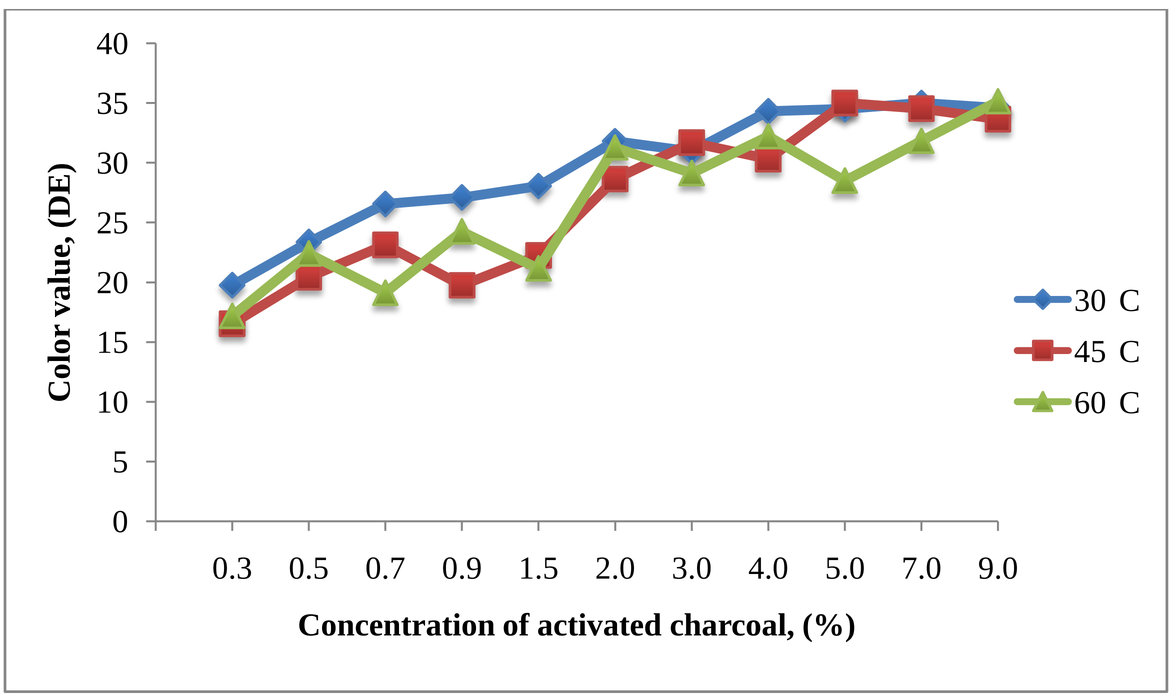


Fig 4.3b. Effect of activated charcoal concentration on the color values of juice for 60 min adsorption duration.

Fig 4.4a CBJ after the treatment with increasing PAC concentration from left to right at adsorption temperature of 30 °C and 30 min adsorption duration

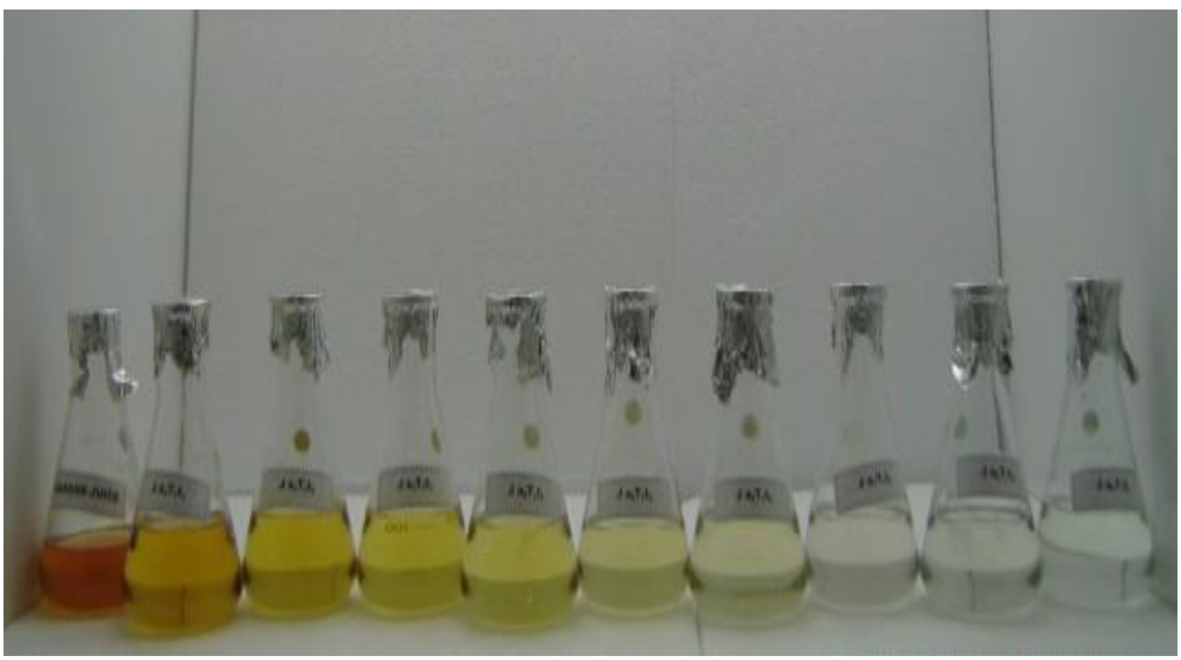


Fig 4.4b CBJ after the treatment with increasing PAC concentration from left to right at adsorption temperature of 30 °C and 60 min adsorption duration.

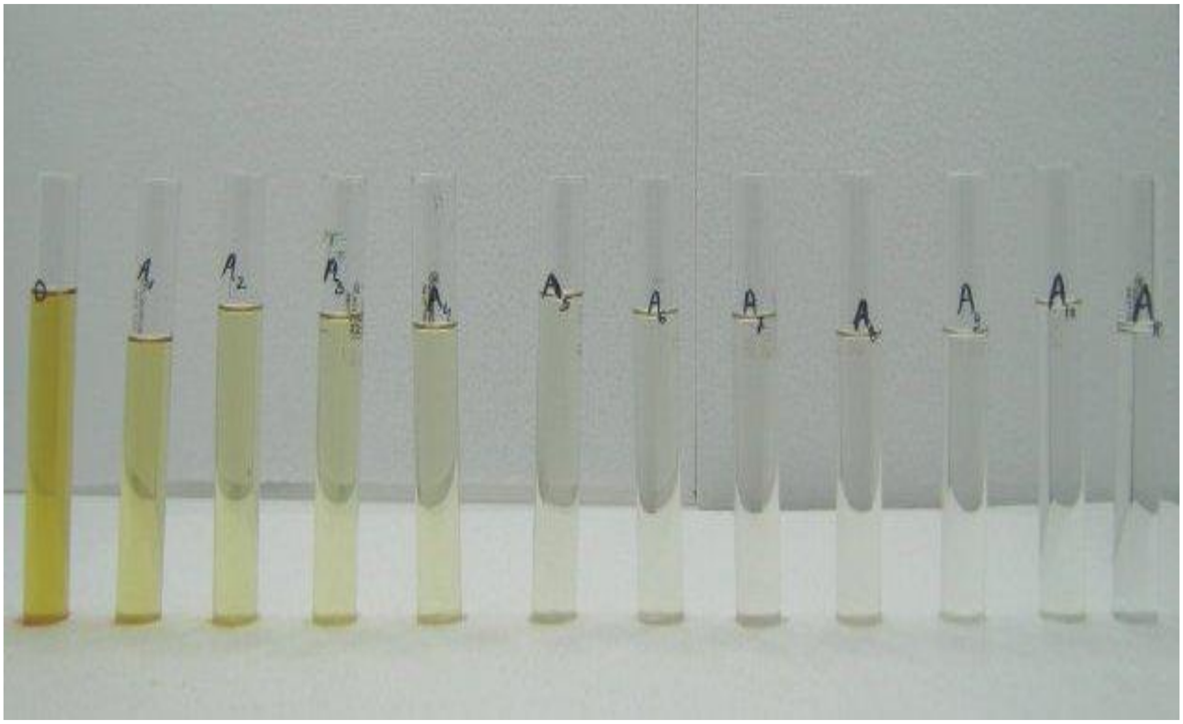


Fig 4.5a CBJ after the treatment with increasing PAC concentration from left to right at adsorption temperature of 60 °C and 30 min adsorption duration.

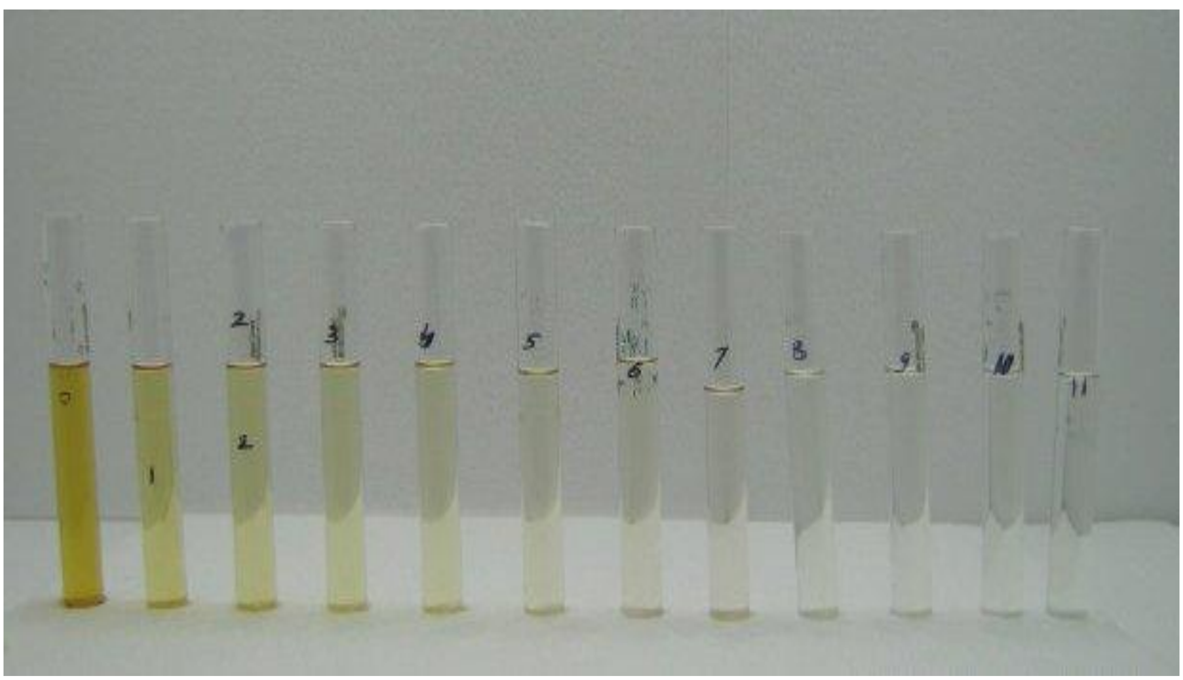


Fig 4.5a CBJ after the treatment with increasing PAC concentration from left to right at adsorption temperature of 60 °C and 60 min adsorption duration

The effect of adsorption temperature for different PAC concentrations on color value of treated clarified banana juice was also studied and shown in Figs. 4.6a and 4.6b. The trend shows that as the temperature of adsorption is increased from 30 to 60 °C, there was some improvement in decoloration for almost all the PAC concentrations and for 30 min of adsorption. However, for lower PAC concentration (0.3 and 0.5 %), the temperature effect was more pronounced. At higher PAC concentrations, the color value was similar for all the treatment temperatures (Fig 4.6a). The effect of temperature of the treatment for prolonged adsorption duration (60 min) was relatively less significant. In fact, the color value reduced to some extent on increase in temperature from 30 to 45 °C for some of the PAC concentrations at 60 min of adsorption (Fig 4.6b).

The maximum color value for 30 min adsorption duration was 33.53 when the adsorption temperature was 60 °C, 7.0 % PAC concentration while the minimum color value was found to be only 11.10 which corresponded to the operating condition of 30°C adsorption temperature, 0.3 % PAC concentration and 30 min adsorption duration. The maximum color value for 60 min adsorption duration was noted 35.14 at operating condition of the highest adsorption temperature of 60 °C and 9.0 % PAC concentration which was also close to 30 °C, 7.0 % PAC concentration.

The results obtained were similar to the findings of Artik *et al.* (1994) who concluded with their studies that the best temperature interval to treat apple juice with activated carbon to improve its color was from 20 to 45 °C but their assay temperatures were 10, 20, and 45 °C. Carbasa *et al* (1998) also observed decrease in absorbance corresponding to lower treatment temperature (10 and 20 °C).

No specific trend was observed for the color value with the variation of adsorption duration of 30 and 60 min at adsorption temperatures of 30, 45 and 60 °C for all the PAC concentrations. Though for many of the samples, the color value increased when the adsorption duration was increased from 30 to 60 min, but, it was not true for all the samples. Hence, it is difficult to explain the influence of adsorption duration on the color value of the treated clarified banana juice. However, it is expected that longer adsorption duration may improve the decoloration of the juice.

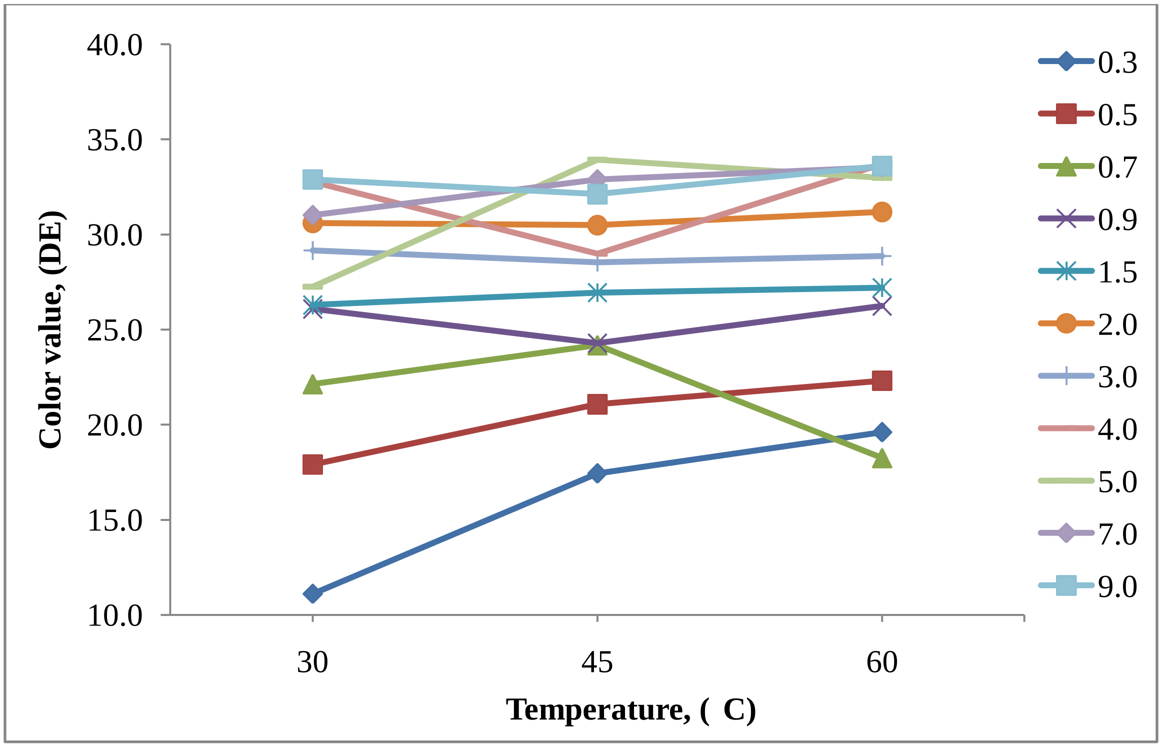


Fig 4.6a. Effect of adsorption temperature on the color values of juice for 30 min adsorption duration

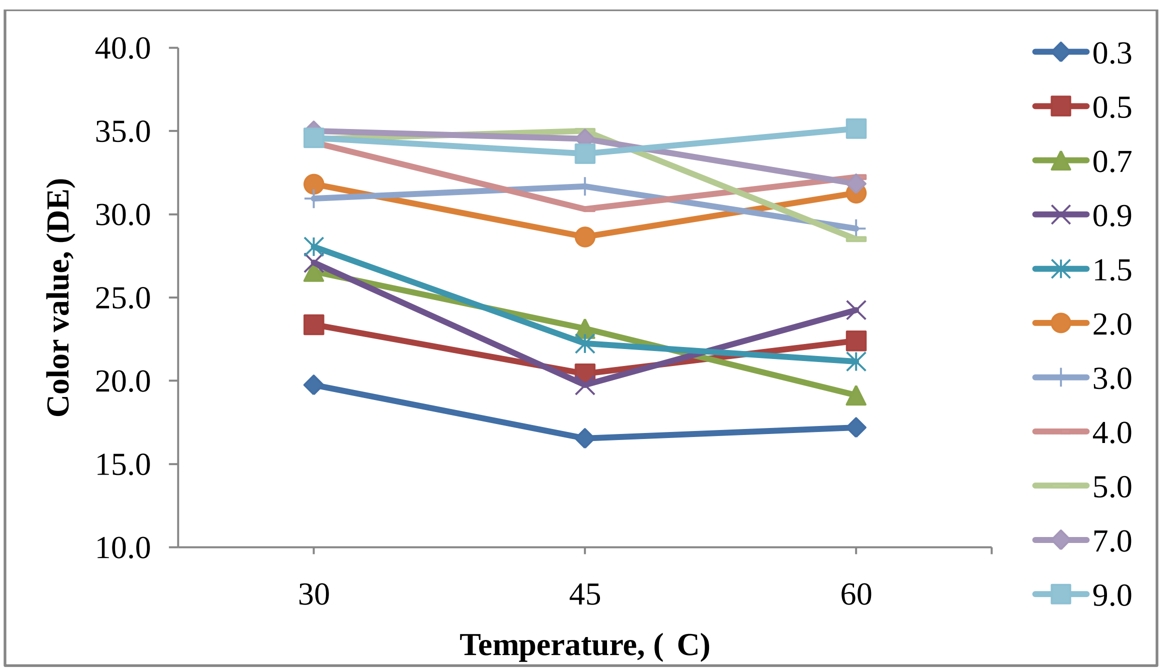


Fig 4.6b. Effect of adsorption temperature on the color values of juice for 60 min adsorption duration

The statistical analysis (Table 4.3) revealed that the calculated F value (F_{CAL}) for adsorption temperature (T), PAC concentration (C), their interaction (T×C), (T×P) and (T×P×C) was higher than the table value (F_{TAB}) indicating the influence of temperature, PAC concentration and their interactions with adsorption duration (P) on color value being significant at 5 % level. The period of adsorption did not significantly affect the decoloration..

Table 4.3 : ANOVA for effect of PAC concentration, adsorption temperature and time and on color value (DE) of the decolored banana juice

Source	D.F	S.S.	M.S.	F_{CAL}	F_{TAB}	S.EM	CD	Test
PAC concentration (C)	10	3526.44	352.644	89.44	1.98	0.5732	1.6212	*
Adsorption temperature (T)	2	42.731	21.365	5.42	3.14	0.2993	0.8466	*
Adsorption duration (P)	1	13.735	13.735	3.48	3.99	0.2444	NS	NS
C *T	20	378.143	18.907	4.80	1.73	0.9928	2.8081	*
T * P	2	152.023	76.012	19.28	3.14	0.4233	1.1974	*
P *C	10	151.567	15.157	3.84	1.98	0.8106	1.6212	*
T * P * C	20	197.144	9.857	2.50	1.73	1.4040	3.9712	*
Error	66	260.23	3.94					
CV	7.273 %							

* significant at 5 % level of significance

4.3. Effect of PAC on Total Soluble Solids of Treated Clarified Banana Juice

It was observed all the decoloring parameters as above had influence on the TSS of the treated clarified banana juice (Table 4.4).

Table 4.4 : Effect of adsorption temperature, time and PAC concentration on TSS of the decolored banana juice

PAC concentration (%)	TSS (°Brix) after treatment at different temperatures and time					
	30min			60min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	15.0	15.0	15.2	15.0	15.0	15.0
0.5	14.9	14.9	15.1	14.9	14.9	15.0
0.7	15.0	15.0	15.0	15.0	15.0	14.9
0.9	15.0	14.9	15.0	14.8	15.0	15.0
1.5	14.4	14.4	14.6	14.6	14.6	14.7
2.0	14.2	14.2	14.4	14.5	14.5	14.6
3.0	14.0	14.1	14.2	14.1	14.2	14.4
4.0	13.3	13.8	14.0	13.8	14.1	14.1
5.0	13.0	13.5	13.7	12.8	13.6	13.9
7.0	12.6	13.0	13.1	12.7	12.8	13.2
9.0	12.4	12.6	12.8	12.5	12.5	12.8

The TSS content of the original clarified banana juice was 15 °Brix which was reduced to below 13 °Brix after the treatment at different adsorption temperatures of 30, 45 and 60 °C and adsorption durations of 30 and 60 min.

It was found (Figures 4.7a and 4.7b) that TSS decreased with increase in the PAC concentration from 0.3 to 9.0 %. This was true for all the adsorption temperatures of 30, 45 and 60 °C and adsorption durations of 30 and 60 min.

The lowest TSS was 12.4 °Brix at the PAC concentration of 9.0 % and the temperature was 30 °C for time was 30 min while the minimum decrease was observed (0.1 °Brix) at 30 and 45 °C adsorption temperatures and for 30 and 60 min adsorption durations for 0.5 % concentration of PAC. The decrease in the TSS was slightly slower with the initial increase in the PAC concentration from 0.3 to 0.9 % for almost all of the treatments. As the PAC concentration further increased beyond 1.5 %, the graphs are relatively steeper. In fact, the TSS decrease continued with the increase in PAC concentration but at slightly faster rate. It can also be seen that the TSS change was very narrow when the PAC concentration increased from 0.3 and 0.9 % corresponding to the 30 and 45 °C adsorption temperatures.

At the same adsorption temperature and time, the decrease in the TSS with the increase in PAC concentration might be due to adsorption of some sugars from the juice. The increased quantity of PAC due to increased concentration might have made more surface area available to adsorb the sugars from the banana fruit juice. Carbasa *et al* (1998) also noticed that the percentage decrease in the soluble solids with increasing concentration of carbon due to more surface area of carbon.

The influence of the temperature of treatment on the variation of TSS in juice was significant for particular concentration of PAC. However, the variation was very small for PAC concentration from 0.3 – 3.0 %. The effect of temperature on TSS of juice was more pronounced for higher concentration (Fig 4.8a and 4.8b). The trend was true for both the duration of adsorption. As the temperature of treatment increased from 30 to 60 °C the TSS increased for the higher doses of PAC. The data also suggest that the variation in TSS as influenced by the duration of treatment was very small, though it was significant (Table 4.6).

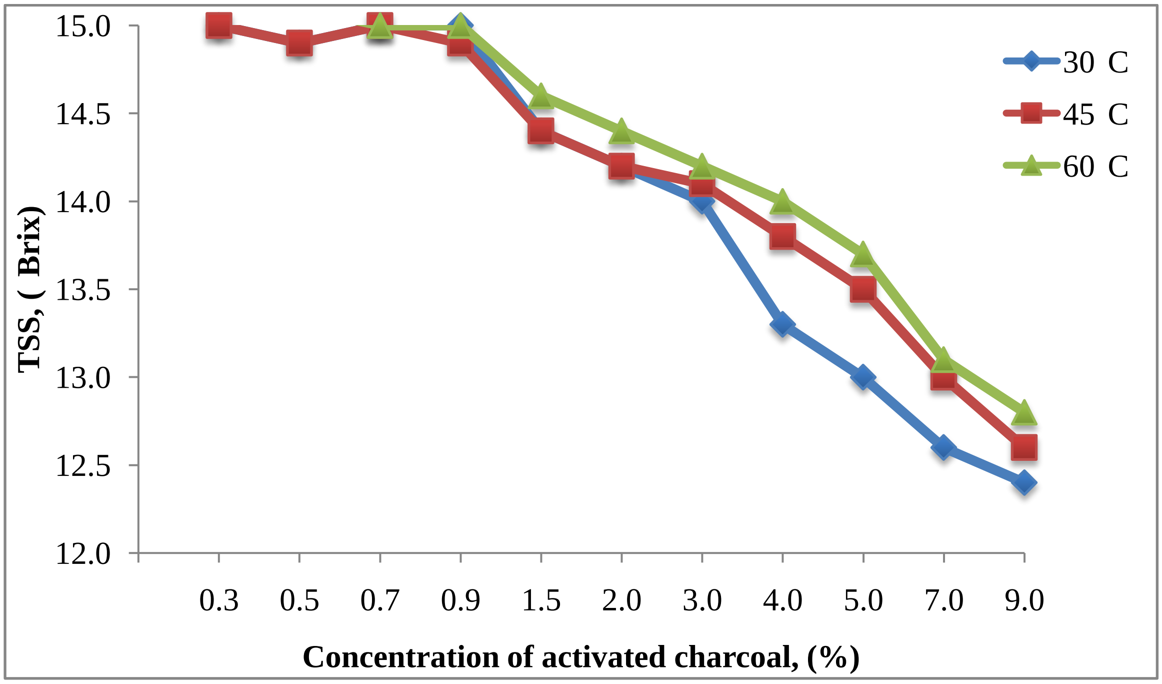


Fig 4.7a. Effect of powdered activated charcoal concentration on the TSS of juice for 30 min adsorption duration

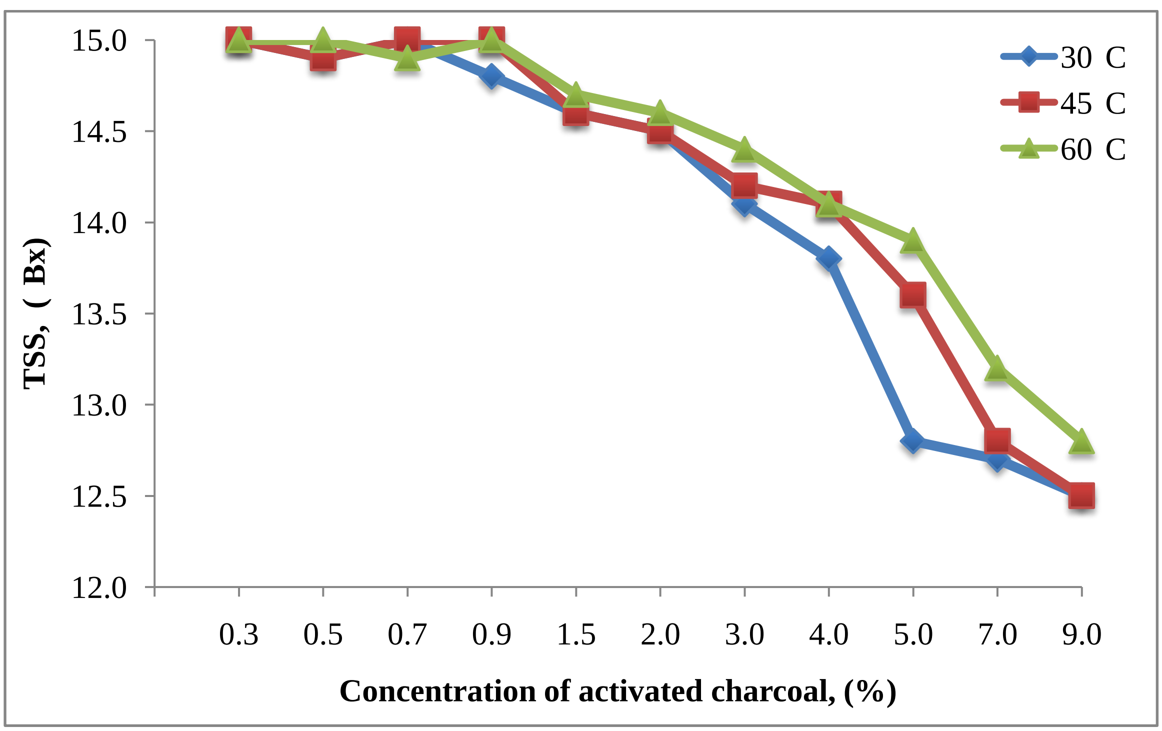


Fig 4.7b. Effect of powdered activated charcoal concentration on the TSS of juice for 60 min adsorption duration

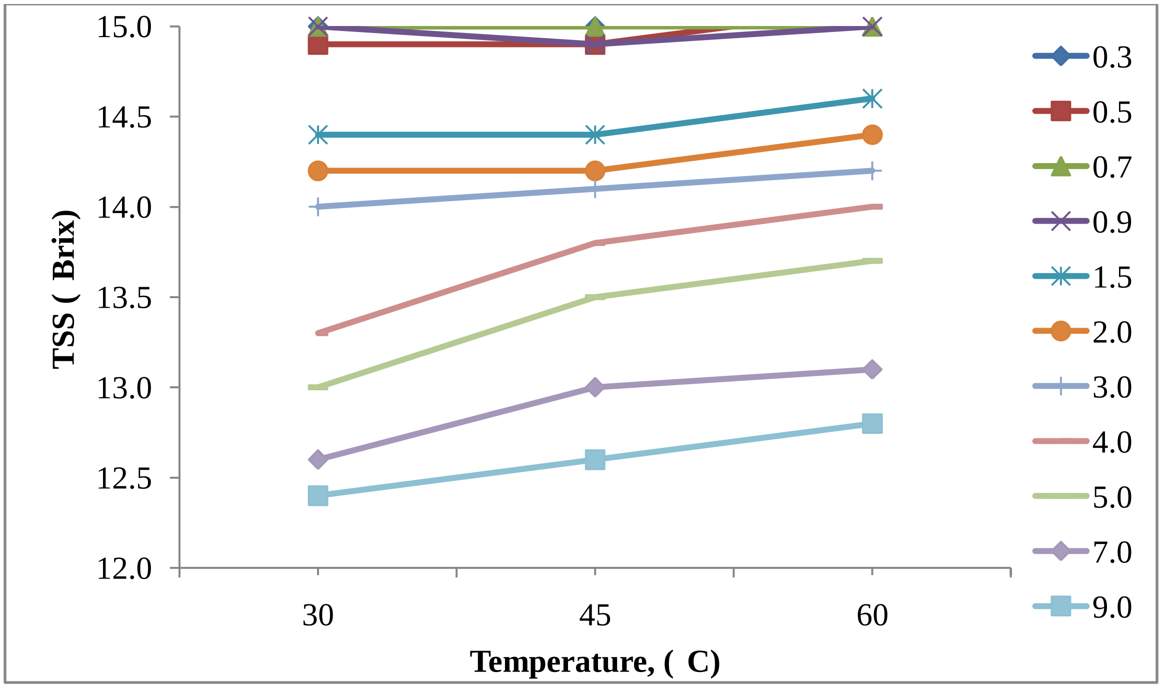


Fig 4.8b Effect of adsorption temperature on the TSS of juice for 30 min adsorption duration.

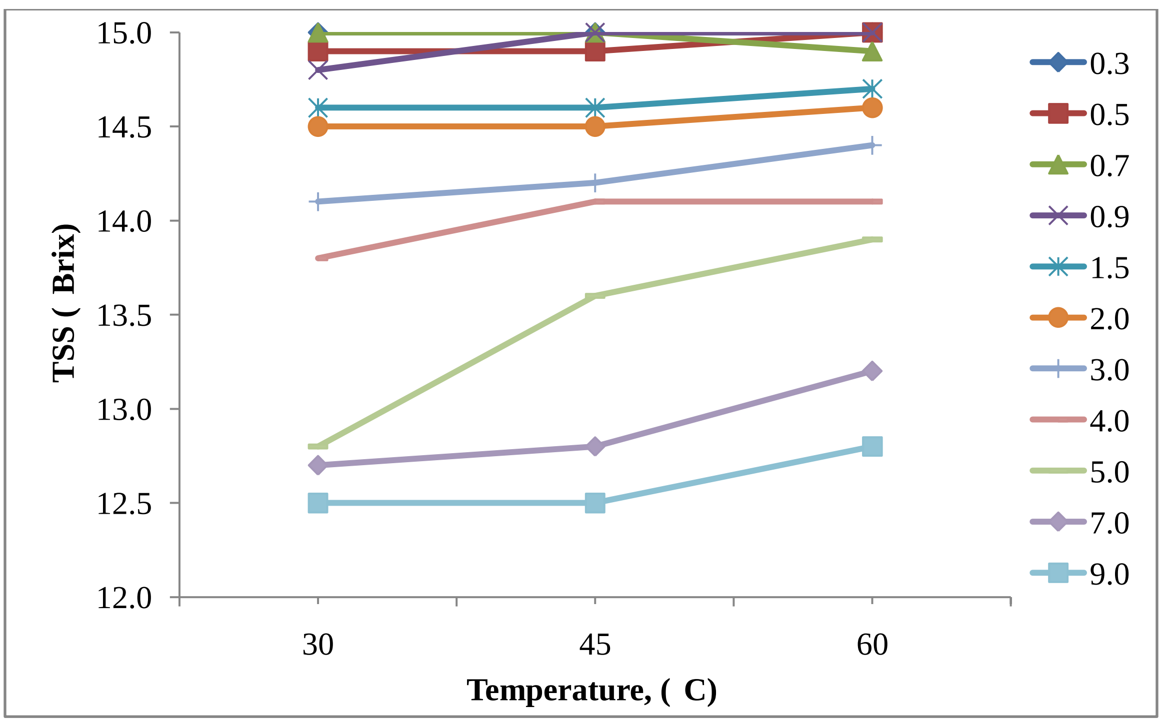


Fig 4.8b Effect of adsorption temperature on the TSS of juice for 60 min adsorption duration.

The statistical analysis (Table 4.5) revealed that the calculated F value (F_{CAL}) for PAC concentration (C), adsorption temperature (T), adsorption duration (P) and their interaction (T×C), (T×P) and (T×P×C) was higher than the table value (F_{TAB}) indicating the influence of PAC concentration temperature (T), adsorption duration (P) on TSS of the treated juice being significant at 5 % level.

Table 4.5 : ANOVA for effect of PAC concentration, adsorption temperature and time and on TSS of the decolored banana juice

Source	D.F	S.S.	M.S.	F_{CAL}	F_{TAB}	S.EM	CD	Test
PAC concentration (C)	10	88.299	8.830	1667.30	1.98	2.100	5.9418	*
Adsorption temperature (T)	2	1.321	0.661	124.73	3.14	1.097	0.0310	*
Adsorption duration (P)	1	0.310	0.310	58.55	3.99	8.957	2.5333	*
C *T	20	2.142	0.107	20.22	1.73	3.638	0.1029	*
T * P	2	0.054	0.027	5.10	3.00	1.551	0.0438	*
P *C	10	0.589	0.059	11.13	1.98	2.970	5.9418	*
T * P * C	20	0.437	0.022	4.12	1.73	5.145	0.1455	*
Error	66	0.34955	5.2959					
CV	0.51523 %							

* significant at 5 % level of significance

4.4 Effect of PAC on pH of Treated Clarified Banana Juice.

The data reveal that there was negligible change in the pH of the juice on varying the concentration of PAC from 0.3 to 9.0 % (Figs 4.9a and 4.9b) at both the durations of treatment (Table 4.6 and Figs 4.9a and 4.9b). However, the pH values for all the experiments at 45 °C were varying absurdly and without any particular relationship. It was difficult to explain the sudden rise in pH of the juice suddenly between 0.9 and 1.5 % concentration of PAC at 45 °C treatment. But, on the basis of the majority data, it was found that the pH of the treated CBJ was almost independent of the adsorption treatments.

Table 4.6 : Effect of adsorption temperature, time and PAC concentration on pH of treated clarified banana juice.

PAC concentration (%)	pH after treatment at different temperatures and time					
	30min			60min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	4.57	3.90	4.51	5.11	4.93	4.55
0.5	4.57	3.91	4.54	5.11	4.95	4.54
0.7	4.57	3.95	4.48	5.10	4.97	4.56
0.9	4.57	3.96	4.52	5.11	4.99	4.55
1.5	4.57	4.50	4.51	5.10	5.00	4.55
2.0	4.57	5.55	4.52	5.12	5.20	4.54
3.0	4.57	5.61	4.51	5.12	5.31	4.52
4.0	4.57	5.65	4.50	5.11	5.43	4.53
5.0	4.57	5.69	4.54	5.15	5.55	4.54
7.0	4.58	5.72	4.57	5.19	5.59	4.52
9.0	4.63	5.75	4.60	5.23	5.64	4.52

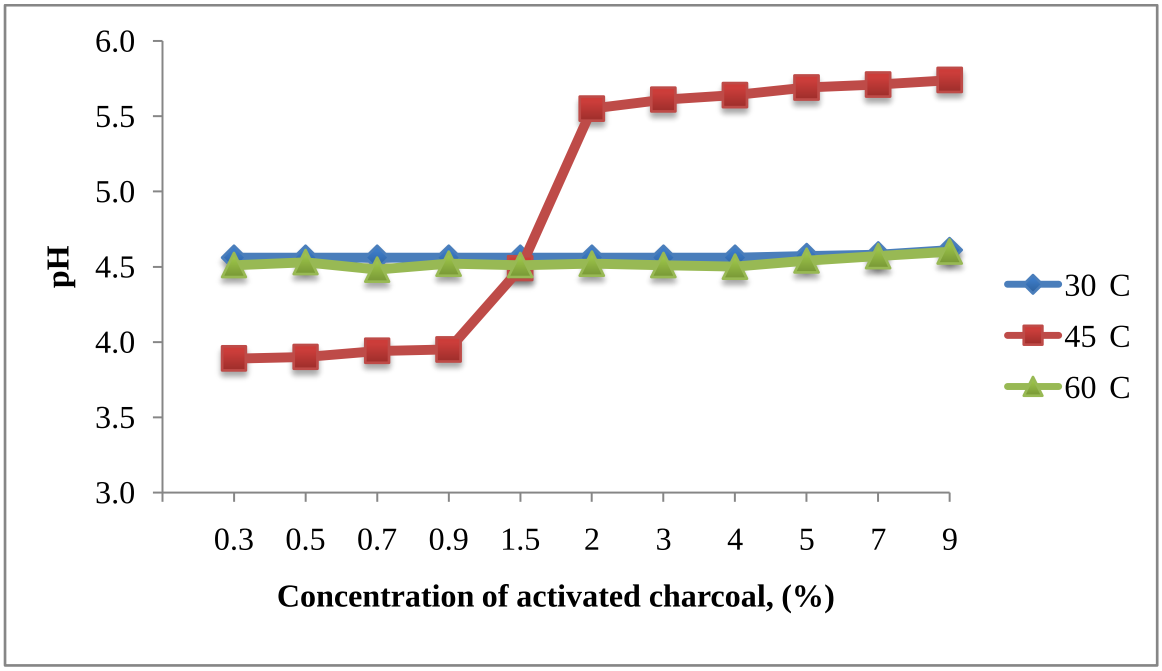


Fig 4.9a. Effect of powdered activated charcoal concentration on the pH of juice for 30 min adsorption duration

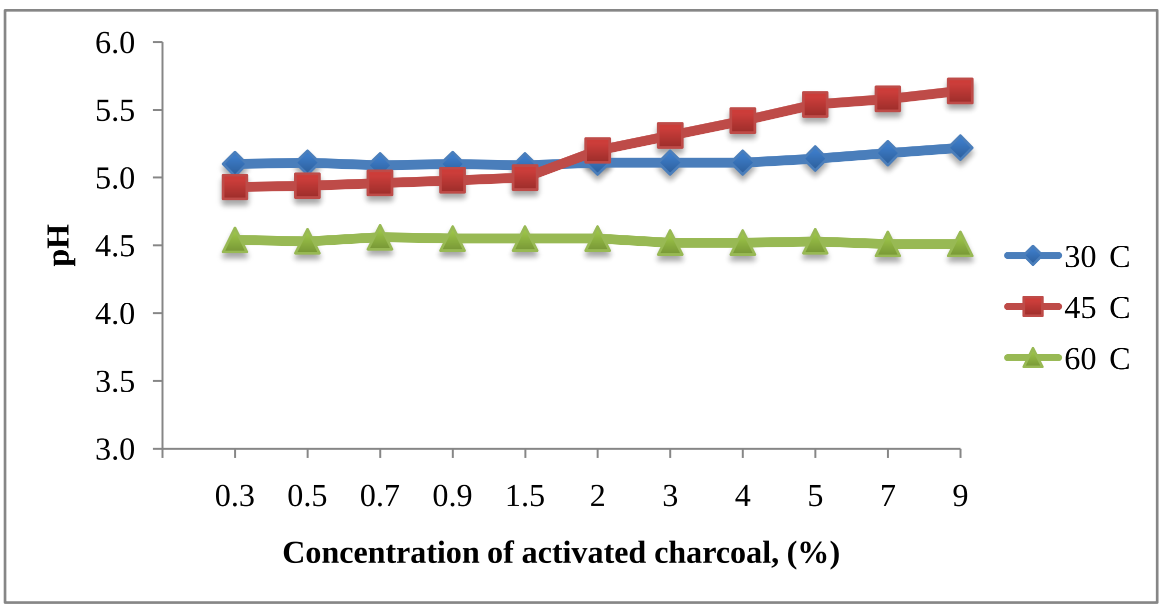


Fig 4.9b. Effect of powdered activated charcoal concentration on the pH of juice for 60 min adsorption duration.

The maximum increase in the pH was 2.25 at 9.0 % PAC concentration 45 °C adsorption temperature and 30 min adsorption duration while the minimum increase in the pH noted was 0.4 at the decoloring condition of 0.3 % PAC concentration, adsorption temperature of 45 °C for 30 min adsorption duration.

On varying the treatment temperature, the pH of the juice also varied for different PAC concentration and for both the period of adsorption (Table 4.6). However, no specific trend was seen for the relationship between temperature of adsorption and pH of the product. The pH values at 45 °C temperature would not fit into any particular variation and they are slightly away from other data obtained or might be due to some experimental error.

The pH of product treated for longer duration shown in variably higher pH. As the PAC used for the experiment had neutral pH (7.0 – 8.0), it is difficult to explain the variation in pH of final product with respect to the treatment parameters.

The statistical analysis (Table 4.7) revealed that the calculated F value (F_{CAL}) for PAC concentration (C), adsorption temperature (T), adsorption duration (P) and their interaction (T×C), (T×P) and (T×P×C) was higher than the table value (F_{TAB}) indicating the influence of PAC concentration temperature (T), adsorption duration (P) on pH of the treated juice was being significant at 5 % level.

Table 4.7 : ANOVA for effect of PAC concentration, adsorption temperature and time and on pH of the decolored banana juice

Source	D.F	S.S.	M.S.	F_{CAL}	F_{TAB}	S.EM	CD	Test
PAC concentration (C)	10	4.676	0.468	4133.10	1.98	3.070	8.6842	*
Adsorption temperature (T)	2	6.851	3.426	30282.26	3.14	1.603	4.5351	*
Adsorption duration (P)	1	2.678	2.678	23668.51	3.99	1.309	3.7029	*
C *T	20	8.355	0.418	3692.68	1.73	5.318	1.5041	*
T * P	2	1.628	0.814	7196.13	3.14	2.267	6.4137	*
P *C	10	1.396	0.140	1233.77	1.98	4.342	8.6842	*
T * P * C	20	2.700	0.135	1193.57	1.73	7.520	2.1271	*
Error	66	7.4663	1.131					
CV	0.22058 %							

* significant at 5 % level of significance

4.5 Effect of PAC on Turbidity of Treated Clarified Banana Juice.

On increasing the PAC concentration from 0.3 to about 1.5-2.0 %, there was increase in the turbidity of the treated juice for all most all the temperature and times of treatment (Table 4.8) but, on further increasing the PAC concentration from 1.5-2.0 % to about 4.0 %, the turbidity reduced and for higher concentration (above 4.0 %), the turbidity was almost constant (Figs 4.10a and 4.10b).

Table 4.8 : Effect of adsorption temperature, time and PAC concentration on turbidity of treated clarified banana juice

PAC concentration (%)	Turbidity (NTU) after treatment at different temperatures and time					
	30 min			60 min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	2.45	1.80	1.25	1.17	1.68	1.30
0.5	3.15	3.80	1.31	1.26	3.37	1.61
0.7	3.20	4.05	1.71	1.54	3.52	2.02
0.9	4.54	4.36	1.94	1.88	4.00	2.44
1.5	5.78	5.03	2.84	2.84	4.70	3.57
2.0	5.68	4.86	2.69	1.56	4.63	3.60
3.0	5.09	3.28	1.60	2.73	3.17	3.40
4.0	2.13	0.66	1.26	1.20	0.70	2.78
5.0	0.51	0.65	0.52	0.45	0.64	2.04
7.0	0.32	0.60	0.37	0.39	0.61	0.83
9.0	0.31	0.56	0.32	0.39	0.44	0.76

As the trends of initial increase in the turbidity and then decreased, was true for almost all the experiments, the PAC concentration definitely had great influence as the turbidity of the treated juice.

The highest turbidity of 5.78 NTU was for all the adsorption treatment with 1.5 % PAC concentration at 30 °C adsorption temperature and 30 min adsorption duration, while the lowest turbidity (0.31 NTU) was observed for the combination of 9.0 % PAC concentration, 30 °C and 30 min adsorption duration (Table 4.8).

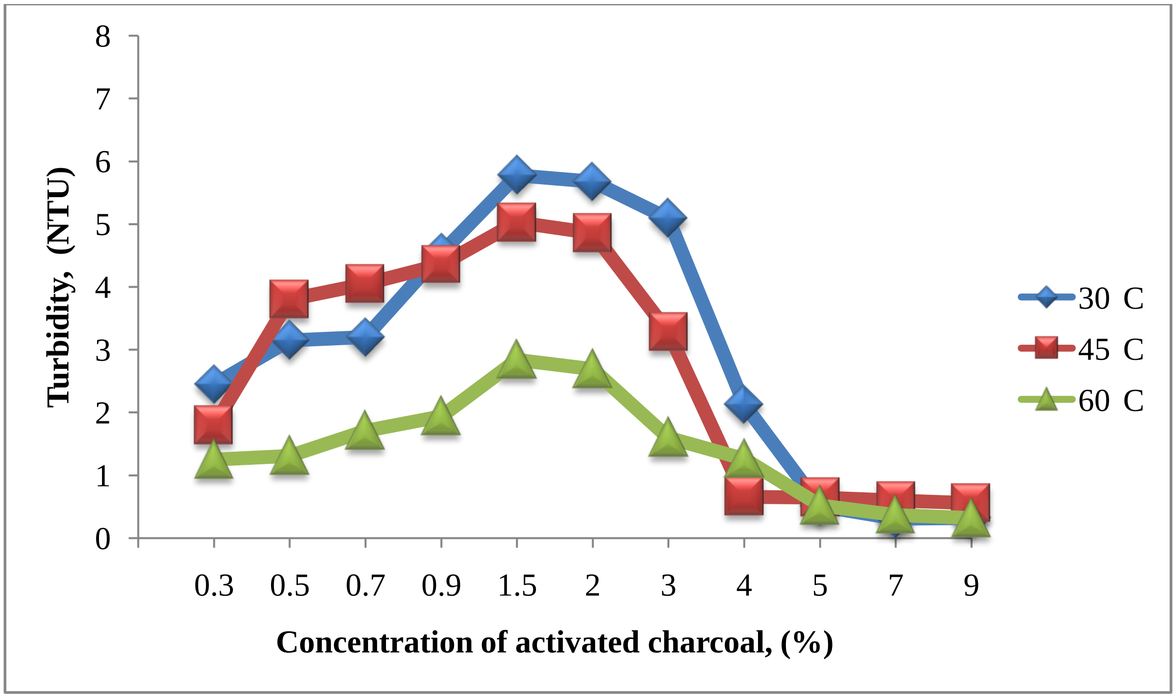


Fig 4.10a. Effect of powdered activated charcoal concentration on the turbidity of juice for 30 min adsorption duration

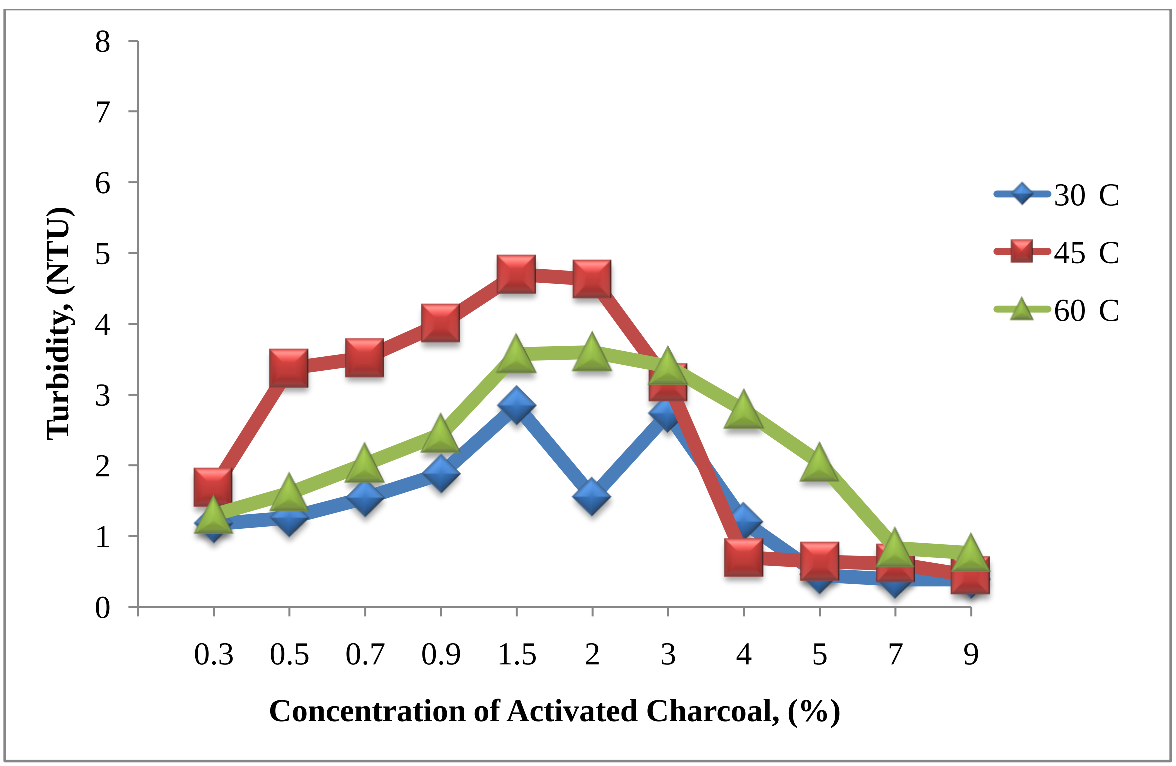


Fig 4.10b. Effect of powdered activated charcoal concentration on the turbidity of juice for 60 min adsorption duration

The turbidity of the treated juice decreased with increase in temperature of treatment from 30 to 60 °C for lower values of PAC concentration and for 30 min adsorption duration (Fig 4.11a). The variation in turbidity for PAC concentration above 7.0 % was almost negligible for both duration of study as the temperature of treatment was varied. The trend for longer period of adsorption was irregular and no particular relationship between temperature of treatment and turbidity of juice could be establish (Fig 4.11b).

The statistical analysis (Table 4.9) revealed that the calculated F value (F_{CAL}) for PAC concentration (C), adsorption temperature (T), adsorption duration (P) and their interaction (T×C), (T×P) and (T×P×C) was higher than the table value (F_{TAB}) indicating the influence of PAC concentration temperature (T), adsorption duration (P) on turbidity of the treated juice was being significant at 5 % level.

Table 4.9 : ANOVA for effect of PAC concentration, adsorption temperature and time and on turbidity of the decolored banana juice

Source	D.F	S.S.	M.S.	F_{CAL}	F_{TAB}	S.EM	CD	Test
PAC concentration (C)	10	212.265	21.226	780.95	1.98	4.7592	0.134	*
Adsorption temperature (T)	2	13.052	6.526	240.10	3.14	2.4854	7.029	*
Adsorption duration (P)	1	13.052	3.935	144.76	3.99	2.0293	5.739	*
C *T	20	30.904	1.545	56.85	1.73	8.2432	0.233	*
T * P	2	31.724	15.862	583.58	3.14	3.1514	9.941	*
P *C	10	7.285	0.729	26.80	1.98	6.7305	0.134	*
T * P * C	20	13.547	0.677	24.92	1.73	0.1165	0.329	*
Error	66	1.79390	2.7180					
CV	7.46787 %							

* significant at 5 % level of significance

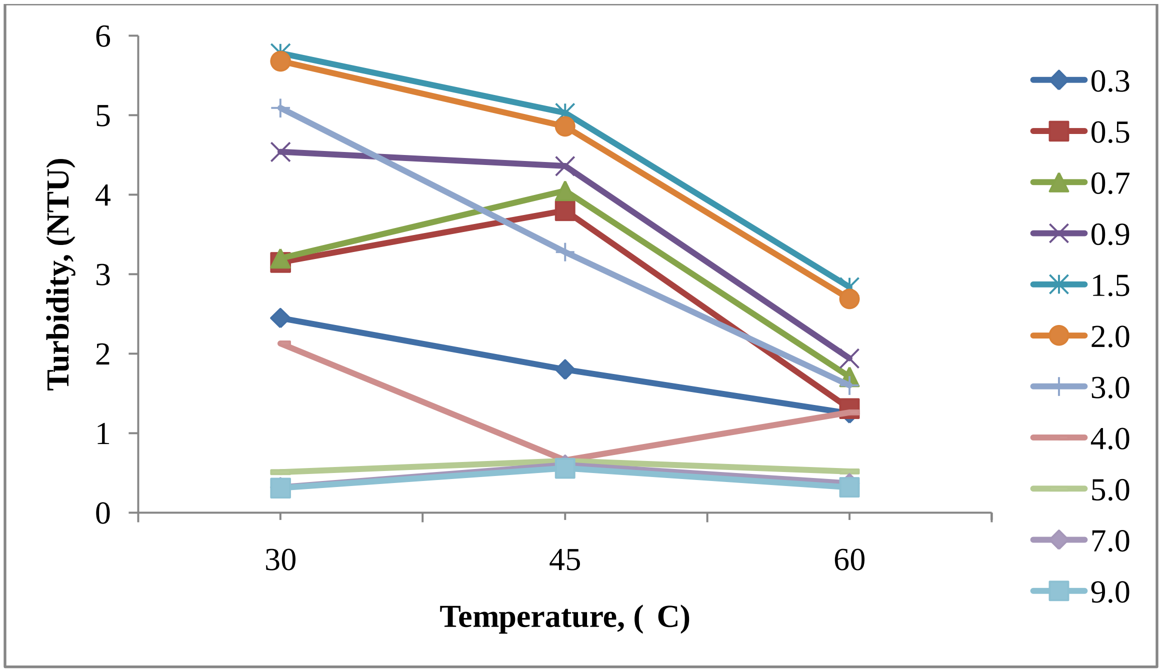


Fig 4.11a. Effect of adsorption temperature on the turbidity of juice for 30 min adsorption duration

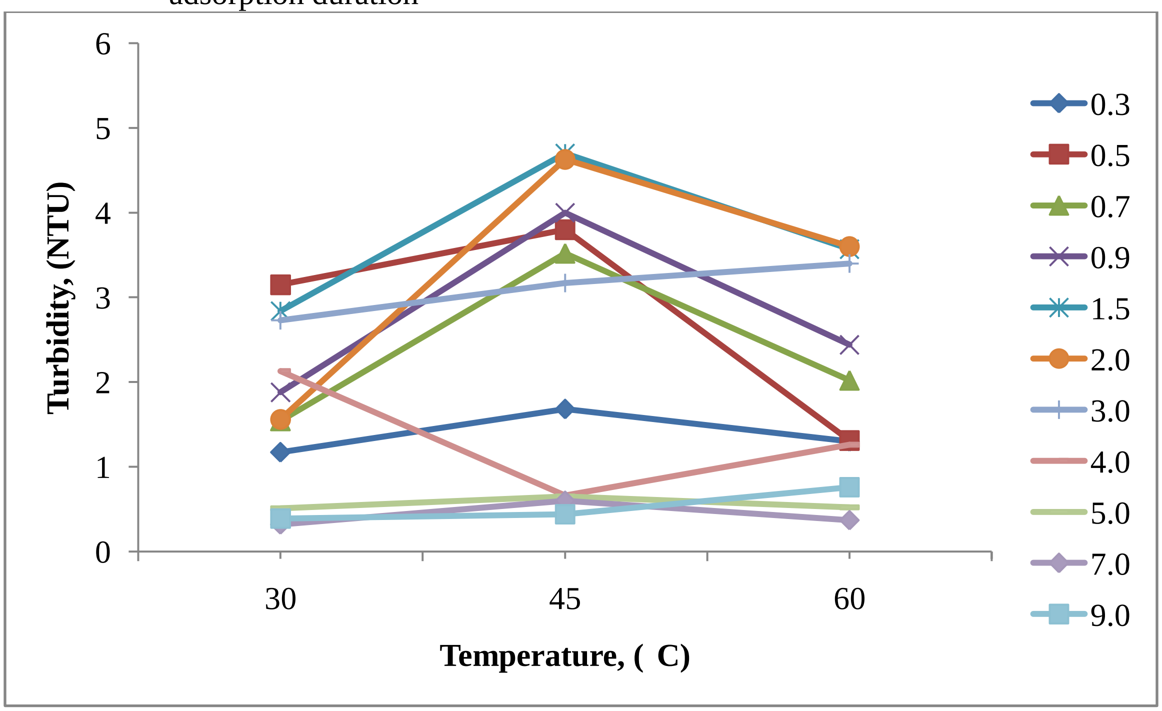


Fig 4.11b. Effect of adsorption temperature on the turbidity of juice for 60 min adsorption duration

4.6 Effect of PAC on Sensory Quality of Treated Clarified Banana Juice

4.6.1 Color

Sensory evaluation was carried for all the treated clarified banana juice samples by trained sensory panel members on the basis of 9 point hedonic scale (Table 4.10).

Table 4.10 : Effect of adsorption temperature, time and PAC concentration on sensory scores of color for treated clarified banana juice

PAC concentration (%)	Color score after treatment at different temperatures and time					
	30 min			60 min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	2.0	1.9	1.4	1.4	1.3	1.8
0.5	2.3	2.6	2.3	2.6	2.4	2.8
0.7	2.7	3.3	3.0	3.7	2.9	3.1
0.9	3.1	4.6	3.2	4.0	3.9	3.6
1.5	3.9	5.5	3.7	4.7	4.4	4.3
2.0	4.4	6.1	4.7	5.4	5.3	4.9
3.0	5.0	6.8	5.0	6.3	6.0	5.4
4.0	5.6	6.6	6.3	6.7	6.0	6.0
5.0	6.4	7.4	7.3	7.6	6.9	6.8
7.0	7.0	8.0	7.9	8.3	8.1	8.3
9.0	7.9	8.4	8.3	9.0	8.4	9.0

It was clearly observed that as the concentration of PAC was increased the color score increased for all the temperatures and adsorption durations (Table 4.10).

The highest color score was 9.0 when the PAC concentration was 9.0 % at adsorption temperature of 30 and 60 °C and adsorption duration was 60 min, while the lowest color score was 1.3 at 45 °C of adsorption temperature, 60 min adsorption duration. The color scores increased constantly with increase in PAC concentration for all the treated samples. In fact, the color score increment continued with the increase in PAC concentration at slower rate. It can be seen that the difference in color score was very narrow when the PAC concentration was increased from 0.3 to 0.9 %.

The effect of adsorption temperature and duration for different PAC concentrations on color was also studied (Table 4.10). The trend shows that when the temperature increased from 30 to 60 °C, the scores increased but the scores were high for 45 °C and 30 min adsorption duration. However, the trend was not similar for 60 min adsorption duration. The data reveals that as the adsorption temperature increased from 30 to 60 °C, the color score decreased for almost all the PAC concentrations. The color scores were significantly affected by all the decoloring parameters.

The statistical analysis (Table 4.11) data presented in Table 4.11 revealed that calculated F value (F_{CAL}) for adsorption temperature (T), PAC concentration (C), their interaction (T×C), (T×P) was higher than table value (F_{TAB}) indicating the influence of temperature, PAC concentration and their interactions with adsorption duration (P) on color value being significant at 5 % level.

Table 4.11 : ANOVA for sensory score for color affected by PAC concentration, adsorption temperature and adsorption duration

Source	D.F	S.S.	M.S.	F_{CAL}	F_{TAB}	S.EM	CD	Test
Adsorption temperature (T)	2	15.650	7.825	19.10	3.02	5.1574	0.1429	*
Adsorption duration (P)	1	6.667	6.667	16.28	3.86	4.2110	0.1167	*
PAC concentration (C)	10	1988.27	198.82	485.38	1.85	9.8758	0.2737	*
T *P	2	40.386	20.193	49.30	3.02	7.2937	0.2021	*
T *C	20	21.242	1.062	2.59	1.60	0.1710	0.4741	*
P *C	10	4.815	0.481	1.18	1.85	0.1396	NS	NS
T * P * C	20	10.364	0.518	1.26	1.60	0.2419	NS	NS
Error	396	162.214	0.4096					
CV	11.1771 %							

*Significant at 5 % level of significance

4.6.2. Flavor

All the decoloring parameters had influence (Table 4.12) on the flavor score of the treated clarified banana juice. The data reveals that the flavor score increased for the increase in the PAC concentration, adsorption temperature and durations.

The highest flavor score was 8.4 at 9.0 % PAC concentration, 45 °C adsorption temperature and 60 min adsorption duration, while the lowest flavor scores was 1.3 at 0.3 % PAC concentration, 45 °C adsorption temperature and 60 min adsorption duration.

As expected, at the same temperature and time, the increase in the flavor score with increase in PAC concentration might be due to increased surface area for adsorption. The increase in the flavor score was narrow for almost all the decoloring parameters.

Table 4.12 : Effect of adsorption temperature, time and PAC concentration on sensory scores of flavor for treated clarified banana juice

PAC concentration (%)	Flavor score after treatment at different temperatures and time					
	30 min			60 min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	2.1	2.0	1.3	2.6	1.3	1.4
0.5	2.6	2.3	2.4	3.4	2.6	2.5
0.7	3.3	3.6	2.6	3.9	4.6	3.2
0.9	3.7	4.1	3.2	4.4	5.8	3.8
1.5	3.9	5.6	3.8	5.5	6.2	4.4
2.0	4.7	6.3	4.6	6.6	7.0	5.1
3.0	4.9	6.9	4.8	7.0	7.1	5.5
4.0	5.6	7.1	5.9	6.8	7.4	6.3
5.0	5.7	7.6	6.1	7.6	7.9	7.2
7.0	6.3	7.7	6.9	7.8	8.0	7.7
9.0	6.6	8.1	7.7	8.1	8.4	8.3

The data shows that when the adsorption temperature was increased from 30 to 60 °C, the flavor score decreased. This was true for both the adsorption duration for almost all the PAC concentrations. But, scores at 45 °C were slightly away for both the adsorption durations.

It was clearly observed that as the adsorption duration was increased from 30 to 60 min for almost all PAC concentrations and adsorption temperatures, the flavor score increased.

The statistical analysis data (Table 4.13) revealed that calculated F value (F_{CAL}) for adsorption temperature (T), PAC concentration (C), their interaction (T×C), (T×P) were higher than table F value (F_{TAB}) indicating the influence of temperature, PAC concentration and their interactions with adsorption duration (P) on color value being significant at 5 % level.

Table 4.13 : ANOVA for flavor affected by PAC concentration, adsorption temperature and adsorption duration

Source	**D.F**	**S.S.**	**M.S.**	**F_{CAL}**	**F_{TAB}**	**S.EM**	**CD**	**Test**
Adsorption temperature (T)	2	105.150	52.575	124.62	3.02	5.2341	0.145	*
Adsorption duration (P)	1	15.273	15.273	36.20	3.86	4.2736	0.1184	*
PAC concentration (C)	10	1452.63	145.26	344.31	1.85	0.1002	0.2778	*
T *P	2	7.899	3.950	9.36	3.02	7.4021	0.2051	*
T *C	20	42.492	2.125	5.04	1.60	0.1735	0.4811	*
P *C	10	4.001	0.400	0.95	1.85	0.1417	NS	NS
T * P * C	20	7.934	0.397	0.94	1.60	0.2455	NS	NS
Error	396	167.071	0.4218					
CV	10.7403							

*Significant at 5 % level of significance

4.6.3 Appearance

The variation in the appearance score of the treated CBJ as influenced by the PAC concentration and temperature-time combination (Table 4.14).

From the below data it was clearly observed that there was increase in appearance score of the juice on varying the concentration of PAC (0.3 to 9.0 %) at all the adsorption temperatures and durations. The flavor score for all the treatments at 45 °C were higher than that at 30 and 60 °C.

Table 4.14 : Effect of adsorption temperature, time and PAC concentration on sensory scores of appearance for treated clarified banana juice

PAC concentration (%)	Appearance score after treatment at different temperatures and time					
	30 min			60 min		
	30 °C	45 °C	60 °C	30 °C	45 °C	60 °C
0.3	1.9	1.4	1.1	2.0	1.7	1.3
0.5	2.4	2.5	2.3	2.9	3.6	2.3
0.7	2.9	4.4	2.7	3.8	4.3	3.0
0.9	3.1	4.7	3.2	4.0	5.1	3.6
1.5	4.0	5.7	3.6	5.0	5.1	4.2
2.0	4.9	5.9	4.2	6.6	6.1	4.4
3.0	5.7	6.6	4.8	7.1	6.6	4.9
4.0	6.0	7.0	5.6	7.8	7.1	5.6
5.0	6.7	6.9	6.5	7.9	7.4	6.9
7.0	7.3	7.3	7.5	8.2	8.0	8.2
9.0	7.9	8.0	8.4	8.6	8.2	8.8

The highest score for appearance was 8.8 when the juice was decolored at 9.0 % PAC concentration, 60 °C adsorption temperature and 60 min adsorption duration while the lowest score was 1.1 for 0.3 % PAC concentration at 60 °C and 60 min adsorption duration.

The effect of temperature on flavor score also observed for all the treated CBJ samples. However, no particular trend was observed for increase in temperature from 30 to 60 °C for all the PAC concentrations and both the adsorption durations. When the adsorption duration was increased from 30 to 60 min the appearance score increased for all the PAC concentrations and adsorption temperatures.

Table 4.15 : ANOVA for appearance affected by PAC concentration, adsorption temperature and adsorption duration

Source	D.F	S.S.	M.S.	F_{CAL}	F_{TAB}	S.EM	CD	Test
Adsorption temperature (T)	2	106.795	53.398	133.29	3.02	5.1003	0.1413	*
Adsorption duration (P)	1	2.014	2.014	5.03	3.86	4.1644	0.1154	*
PAC concentration (C)	10	1736.46	173.64	433.45	1.85	9.7664	0.2707	*
T *P	2	1.105	0.552	1.38	3.02	0.0721	NS	NS
T *C	20	85.347	4.267	10.65	1.60	0.1691	0.4688	*
P *C	10	4.195	0.419	1.05	1.85	0.1381	NS	NS
T * P * C	20	8.062	0.403	1.01	1.60	0.2392	NS	NS
Error	396	158.642	0.4006					
CV	10.52055 %							

*Significant at 5 % level of significance

The statistical analysis data (Table 4.15) revealed that calculated F value (F_{CAL}) for adsorption temperature (T), adsorption duration (P), the interaction of (T×C), (T×P) were higher than table value (F_{TAB}) indicating the influence of temperature, PAC concentration and their interactions with adsorption duration (P) on flavor value being significant at 5 % level.

4.7 Optimization of Decoloring Parameters

Though, all the observations recorded were important, but to optimize the decoloring conditions, the maximum color value was considered the deciding factor and hence, the parameters were optimized based on the maximum color value of the decolored clarified banana juice.

The optimized conditions obtained were;

Adsorbent: Powdered activated charcoal.

PAC concentration: 9.0 %

Adsorption temperature: 60 °C

Adsorption duration: 60 min.

Final bulk sample of decolored clarified banana juice was prepared employing the above mentioned optimized conditions. The final sample was analyzed for its chemical qualities.

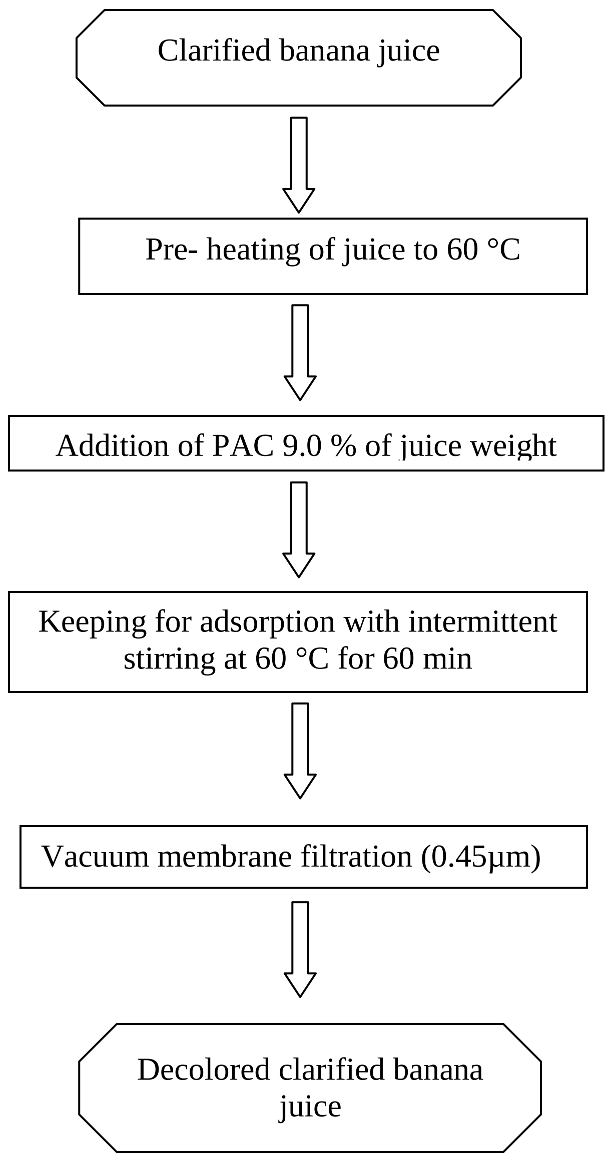
4.7.1 Chemical quality of fresh and decolored clarified banana juice

The color value of the fresh clarified banana juice was 0 and that of decolored clarified banana juice was 35.14. The TSS in fresh clarified banana juice was 15 °Brix and that of decolored clarified banana juice was 12.8 °Brix. The pH of the fresh clarified banana juice was 3.50 and that of decolored clarified banana juice was 4.52. The average turbidity of fresh clarified banana juice was about 22 NTU and in decolored clarified banana juice was 0.76 NTU. The turbidity was expressed in NTU. The percent titrable acidity of the fresh clarified banana juice was 0.19 % and that of decolored clarified banana juice after decoloration was 0.10 %. The total, reducing sugar and non reducing sugar content in the fresh clarified banana juice was 14.02, 8.25 and 5.77 % while that in decolored clarified banana juice was 8.55, 5.39 and 3.16 %, respectively. The average initial ascorbic acid content in fresh clarified banana juice was about 8 mg/100ml of juice and 4 mg/ 100ml in decolored clarified banana juice (Table 4.16).

Table 4.16 : Chemical quality of fresh and decolored clarified banana juice

S. No.	Parameters	Mean value	
		Fresh clarified banana juice	**Decolored clarified banana juice**
1	Color value (DE)	0.0	35.14
2	TSS (°Brix)	15.0	12.8
3	pH	3.50	4.52
4	Turbidity (NTU)	22.00	0.76
5	Titrable acidity (%)	0.19	0.10
6	Total Sugars (%)	14.02	8.55
7	Reducing Sugars (%)	8.25	5.39
8	Non reducing sugars (%)	5.77	3.16
9	Ascorbic acid (mg/100ml)	8.00	4.00
10	Titrable acidity (%)	0.19	0.10

4.8 Protocol for Decoloration of Clarified Banana Juice



CHAPTER V

SUMMARY AND CONCLUSIONS

India is one of the most important fruit producing nations in the world, accounting for about 10.4 percent of all fruits and nearly 40 percent of tropical fruits produced globally. Banana fruit is consumed by millions of people around the world as part of their daily diet and for nutrient enrichment.

Now days, there is a rising trend of consuming natural and fresh fruit juices. Juices are products for direct consumption and are obtained by the extraction of cellular juice from fruits. Banana is one of the tropical and economical fruits of India and available at relatively cheaper rate for most part of the year. However, banana juice when blended with other fruit juices imparts its undesirable color and flavor. Hence, need was felt to develop the decoloring and deflavoring system for banana juice.

Most of the work on banana is related to the post harvest technology for banana, ripening changes during harvesting, nutritive value of the fresh fruit, different methods for extraction of banana juice, clarification methods and preparation of processed products like puree, wine, adjuncts in beer, banana chips, wafers, banana concentrate, banana powder, etc. Decoloration helps commercial exploitation of clarified banana juice. However, little or no published information available on decoloring of clarified banana juice. Therefore, the present investigation was undertaken to study the effect of different decoloring systems on the color value and chemical quality of the decolored banana juice. Keeping above facts in mind and with a view to develop a comprehensive technology for the decoloration of clarified banana juice; a systematic research study is proposed to be undertaken.

The objectives of the study are listed as under:

1. To study different decoloration systems for clarified banana fruit juice.
2. To develop a decoloring system, for clarified banana fruit juice.
3. To standardize the process protocol for decoloration of banana fruit juice.

The experiments were conducted at JAIN IRRIGATION SYSTEM LTD. JALGAON. The clarified banana juice concentrate of 65-66 °Brix was procured from the M/s Jain Food Park. The clarified banana juice of 15 °Brix was prepared by adding the calculated amount of distilled water. The clarified banana juice was decolored using adsorption method. The different decoloring variables tested were two types of adsorbents, eleven concentrations of the adsorbent, three temperatures of the adsorption, two durations for adsorption for their influence on the color value juice, TSS, pH, turbidity of the treated juice. The final decolored juice was evaluated for its chemical quality.

The clarified banana juice was decolored using two different adsorbents i.e. powdered activated charcoal and bentonite at different adsorbent concentrations ranging from 0.3 to 9.0 g/100g of juice and 0.3 to 0.9 g/100g of juice, respectively, adsorption temperatures 30, 45 and 60 °C and adsorption duration of 30 and 60 min. The hot water bath temperature was maintained by controlling the electric heaters by digital temperature controller. The process was standardised with the maximum color value. The best sample with maximum color value was used for further study of chemical properties of decolored clarified banana juice.

Conclusions:

1. There was very little effect of bentonite on the degree of decoloration of clarified banana juice. The maximum DE value was obtained at adsorption temperature of 60 °C, adsorption duration of 60 min and at 0.7% concentration. Further increasing the bentonite concentration did not show any appreciable effect on the degree of decoloration.
2. The bentonite had good effect on reducing the turbidity of the treated clarified banana juice. The highest reduction in the turbidity was 11.87 NTU found at 30 °C adsorption temperature, 30 min adsorption duration and 0.9 % bentonite concentration.
3. No specific trend was seen for the TSS reduction with the variation adsorption temperature from 30 to 60 °C and bentonite concentration from 0.3 to 0.9 % at adsorption duration of 30 and 60 min. The TSS was decreased from 15 °Brix to

14.5 °Brix at 0.9 % bentonite concentration, 30 °C adsorption temperature and 60 min adsorption duration.

4. Bentonite had very less effect on the pH of the treated clarified banana juice. The maximum increase in the pH was 1.30 noted at 45 °C adsorption duration 0.5 % adsorbent dose and 30 min adsorption duration.
5. The powdered activated charcoal (PAC) had great effect on decoloration of clarified banana juice. It was concluded that as the PAC concentration was increased from 0.3 to 9.0 %, the degree of decoloration increased. The maximum color value was obtained at 9.0 % PAC concentration was 35.14.
6. It was also observed that as the temperature of treatment increased from 30 to 60 °C, the degree of decoloration increased. The adsorption duration had no any significant effect on the degree of decoloration. The maximum color value was 35.14 at 9.0 % PAC concentration, 60 °C adsorption temperature and 60 min adsorption duration.
7. The TSS of the treated CBJ decreased with increase in the PAC concentration. The maximum decrease in the TSS was 3.6 observed at 30 °C adsorption temperature, 9.0 % PAC concentration and adsorption duration of 30 min.
8. The variation in the PAC concentration and adsorption temperature within the range tested during decoloring process had no specific effect on the pH of the treated banana juice.
9. No specific trend was seen for the relationship between temperature of adsorption and pH of the product. The pH increased from 3.50 to 5.75 found at 9.0 %, adsorption temperature 45 °C and 30 min adsorption duration.
10. On increasing the PAC concentration from 0.3 to about 1.5-2.0 %, there was increase in the turbidity of the treated juice for all most all the temperatures and times of treatment but, on further increasing the PAC concentration from 1.5-2.0 % to about 4.0 %, the turbidity reduced and for higher concentration (above 4.0 %), the turbidity was almost constant.
11. No particular relationship between temperature of treatment and turbidity of juice could be established for particular adsorption duration.

12. The optimized decoloring parameters for the maximum color value were:

Type of adsorbent	: powdered activated charcoal
Adsorbent concentration	: 9.0 %
Adsorption temperature	: 60 °C
Adsorption duration	: 60 min

13. The final decolored clarified banana juice obtained from optimized decoloring conditions had 35.14 color value, 12.8 °Brix TSS, 4.52 pH, 0.76 NTU turbidity, 0.10 % titrable acidity, the total sugar, reducing sugar and non reducing sugar content 8.55, 5.39 and 3.16 %, respectively, ascorbic acid 4 mg/ 100ml.

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APPENDIX I

Decoloration Data for Clarified Banana Fruit Juice

Adsorbent	Concentration (%)	Adsorption Time (min)	Temp (°C)	Color values (DE)	TSS (°Brix)	Turbidity (NTU)	pH
Bentonite	0.3	30	30	6.11	15.0	1.10	3.50
			45	1.98	15.0	1.16	4.79
			60	3.02	15.0	1.22	3.66
		60	30	4.00	14.9	1.07	3.47
			45	0.93	15.0	1.17	4.69
			60	4.14	15.0	1.23	3.69
	0.5	30	30	4.86	15.0	0.91	3.66
			45	4.77	14.9	1.11	4.80
			60	4.46	14.9	1.15	3.79
		60	30	5.29	15.0	0.91	3.58
			45	2.14	14.9	1.12	4.68
			60	1.78	15.0	1.14	3.83
	0.7	30	30	5.57	15.0	0.86	3.89
			45	9.14	15.0	0.96	4.77
			60	10.74	15.0	0.97	3.97
		60	30	4.22	14.7	0.88	3.91
			45	2.41	14.8	0.97	4.67
			60	11.29	14.7	0.97	4.01
	0.9	30	30	3.94	14.9	0.73	4.10
			45	6.55	15.0	0.86	4.77
			60	3.91	15.0	0.85	4.36
		60	30	5.10	14.5	0.79	4.20
			45	4.33	14.6	0.85	4.67
			60	4.73	14.6	0.87	4.38
Activated Charcoal	0.3	30	30	11.10	15.0	2.45	4.57
			45	17.43	15.0	1.80	3.90
			60	19.60	15.2	1.25	4.51
		60	30	19.74	15.0	1.17	5.11
			45	16.53	15.0	1.68	4.93
			60	17.18	15.0	1.30	4.55
	0.5	30	30	17.91	14.9	3.15	4.57
			45	21.07	15.0	3.80	3.91
			60	22.31	15.1	1.31	4.54
		60	30	23.36	14.9	1.26	5.11
			45	20.42	14.9	3.37	4.95
			60	22.39	15.0	1.61	4.54
	0.7	30	30	22.14	15.0	3.20	4.57
			45	24.18	15.0	4.05	3.95
			60	18.25	15.0	1.71	4.48
		60	30	26.55	15.0	1.54	5.10
			45	23.13	15.0	3.52	4.97
			60	19.12	14.9	2.02	4.56

	0.9	30	30	26.09	15.0	4.54	4.57
			45	24.28	14.9	4.36	3.96
			60	26.24	15.0	1.94	4.52
		60	30	27.09	14.8	1.88	5.11
			45	19.74	15.0	4.00	4.99
			60	24.25	15.0	2.44	4.55
	1.5	30	30	26.30	14.4	5.78	4.57
			45	26.95	14.4	5.03	4.50
			60	27.21	14.6	2.84	4.51
		60	30	28.05	14.6	2.84	5.10
			45	22.24	14.6	4.70	5.00
			60	21.15	14.7	3.57	4.55
	2.0	30	30	30.61	14.2	5.68	4.57
			45	30.49	14.2	4.86	5.55
			60	31.19	14.4	2.69	4.52
		60	30	31.81	14.5	1.56	5.12
			45	28.63	14.5	4.63	5.20
			60	31.27	14.6	3.60	4.54
	3.0	30	30	29.16	14.0	5.09	4.57
			45	28.55	14.1	3.28	5.61
			60	28.86	14.2	1.60	4.51
		60	30	30.94	14.1	2.73	5.12
			45	31.68	14.2	3.17	5.31
			60	29.13	14.4	3.40	4.52
	4.0	30	30	32.77	13.3	2.13	4.57
			45	28.98	13.8	0.66	5.65
			60	33.71	14.0	1.26	4.50
		60	30	34.30	13.8	1.20	5.11
			45	30.30	14.1	0.70	5.43
			60	32.22	14.1	3.78	4.53
	5.0	30	30	28.50	13.0	0.51	4.57
			45	33.93	13.5	0.65	5.69
			60	32.98	13.7	0.52	4.54
		60	30	34.49	12.8	0.45	5.15
			45	35.00	13.6	0.64	5.55
			60	29.45	13.9	2.04	4.54
	7.0	30	30	31.01	12.6	0.32	4.58
			45	32.89	13.0	0.60	5.72
			60	33.53	13.1	0.37	4.57
		60	30	35.00	12.8	0.39	5.19
			45	34.53	12.7	0.61	5.59
			60	31.83	13.2	0.83	4.52
	9.0	30	30	32.90	12.4	0.32	4.63
			45	32.12	12.6	0.56	5.75
			60	33.60	12.8	0.31	4.60
		60	30	34.59	12.5	0.39	5.23
			45	33.64	12.5	0.44	5.64
			60	35.14	12.8	0.76	4.52

APPENDIX II

SENSORY EVALUATION SCORE CARD
(Hedonic Scale)

Name: - Date:-

Product: - Decolored clarified banana juice Time:-

1. Kindly evaluate the product using 9 point hedonic scale followed by your valuable remarks and comments.
2. Remember you are the only one who can tell us what you like.
3. An honest expression of your personal feeling will help us.
4. Sensory is based on degree of decoloration and deflavoration

Sensory characteristics / Samples	Colour	Flavor	Appearance
A			
B			
C			

Evaluation guidance:
9 - Like extremely
8 - Like very much
7 - Like moderately
6 - Like slightly
5 - Neither like nor dislike
4 - Dislike slightly
3 - Dislike moderately
2 - Dislike very much
1 - Dislike extremely

Remarks/Comments:-

Name and Signature of panelist