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Permanganate Infusion: A Novel Approach to Activated Charcoal Modification

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ABSTRACT: *To develop a modified potassium permanganate-infused activated material with improved efficiency in ethylene absorption for extended freshness of perishable goods. Ethylene absorption properties of activated charcoal were improved by strong bases and potassium permanganate (KMnO4) at concentrations of 1M, 2M and 3M. Activated charcoal was soaked in a 5 w/v% solution of KMnO4 for overnight and then filtered and the powder is collected and dried. The effects of ethylene absorbers with charcoal-$KMnO_4$ and without as control on bananas during storage at room temperature were investigated.*
Keywords: *KMnO4, Activated Charcoal, Fruits ripening, etc*

INTRODUCTION

Fruits are generally divided in two categories: climacteric and non-climacteric fruits Ethylene, a natural plant hormone, it acts as a key signalling molecule in the ripening process of climacteric fruits. Changes that take place are increased Respiration, Softening, Colour Changes etc. [1 to 5]

Non-climacteric fruits do not show the same ethylene response Their ripening is more tightly controlled by other hormones, such as abscisic acid, rather than by ethylene. An ethylene absorber is a substance used to remove ethylene gas from the environment By absorbing ethylene, these absorbers help slow down the ripening and spoilage of climacteric fruits.[6,7,8]

MATERIALS & METHODS

1. Ethylene Absorber

Ethylene absorbers contain compounds that react with or trap ethylene molecules, thereby reducing its concentration in the storage environment. The most common materials used in ethylene absorbers are potassium Permanganate ($KMnO_4$) Activated Carbon, Zeolite, etc [9-14]

2. Potassium Permanganate Infusion

When infused into a porous material, potassium permanganate increased surface area and stability then allowing it to react with Ethylene. Ethylene molecules diffuse through the pores of the material and come into contact with potassium permanganate, which oxidizes the ethylene into carbon dioxide and water (Fig 1).[15-17]

Fig. 1 : Ethylene molecules reacting with KMnO4 giving CO_2 and H_2O.

3. Procedure

Activated Charcoal were soaked in 100 mL of 5 w/v% $KMnO_4$ solution prepared from dry powder for 24 hours; Then 1g of each compound was packed in the sachets. Bananas were purchased from a local

trader and used for the analysis of their ripening. The samples were divided into four categories with concentration of 0M, 1M, 2M and 3M.[18-23]
Following changes were observed in complete one week from day1 till day7 (Fig 2 & 3).

Fig 2: $KMnO_4$ solution prepared using powdered charcoal

DAY 1

DAY 7

DAY 8

DAY 11

DAY 15

DAY 21

Fig 3: Changes observed in ripening of banana

From the observations of Day 1 to Day 21, most effective ethylene absorber was of the highest concentration i.e. 3M. And we can use this as Anti-ripening agent to slow down the ripening process by absorbing the ethylene gas from fruits.

RESULT AND DISCUSSION

In the study of fruit ripening, especially bananas, various methods have been explored to delay or control the ripening process. One such method involves the use of activated charcoal, which has been suggested to play a significant role in regulating the ripening rates of fruits, including bananas. The role of hydroxyl groups in activated charcoal can provide insight into the mechanisms behind this delay in ripening.

Spectral Analysis of Activated Charcoal

One practical method for locating functional groups in a material is infrared (IR) spectroscopy. The hydroxyl (-OH) group is represented as peaks in the IR spectra of activated charcoal, which range from 3000 to 3700 cm-1 as shown in figure 4 [24]. The stretching vibrations of the O-H bond are usually linked to the wide absorption band in this area, which suggests the presence of hydroxyl groups. Hydrogen connections with water molecules are frequently formed by these hydroxyl groups.
Furthermore, the spectra frequently show a peak at about 1650 cm-1, which is ascribed to the hydroxyl group's bending vibrations. This characteristic implies that trapped water molecules are present inside the

activated charcoal's porous structure. Given that it may interfere with the fruit's physiological functions, activated charcoal's capacity to absorb and retain water molecules is crucial in this situation. [25,26]

Delayed Ripening of Bananas and the Role of Activated Charcoal

Ethylene, a naturally occurring plant hormone that speeds up the conversion of starch to sugar, is known to cause bananas to ripen quickly. However, it has been shown that the ripening process may be considerably slowed down by employing activated charcoal. The fruit's physical and chemical interactions with the activated charcoal, especially the trapped water molecules inside the porous structure, are the main cause of this delay.[27,28]

The fruit's surrounding moisture equilibrium is probably maintained by the hydroxyl groups in activated charcoal. Charcoal may decrease the amount of free water surrounding the fruit's surface by absorbing extra moisture, which would slow down ripening-related enzyme activities. A microenvironment that limits the activity of ethylene may also be created by the water trapped in the pores of activated charcoal, which would further delay the ripening process.[29,30]

In addition, the presence of hydroxyl groups can also affect the adsorption of other volatile compounds, including ethylene. This interaction could help regulate the levels of ethylene in the vicinity of the fruit, thus further slowing down the ripening process.

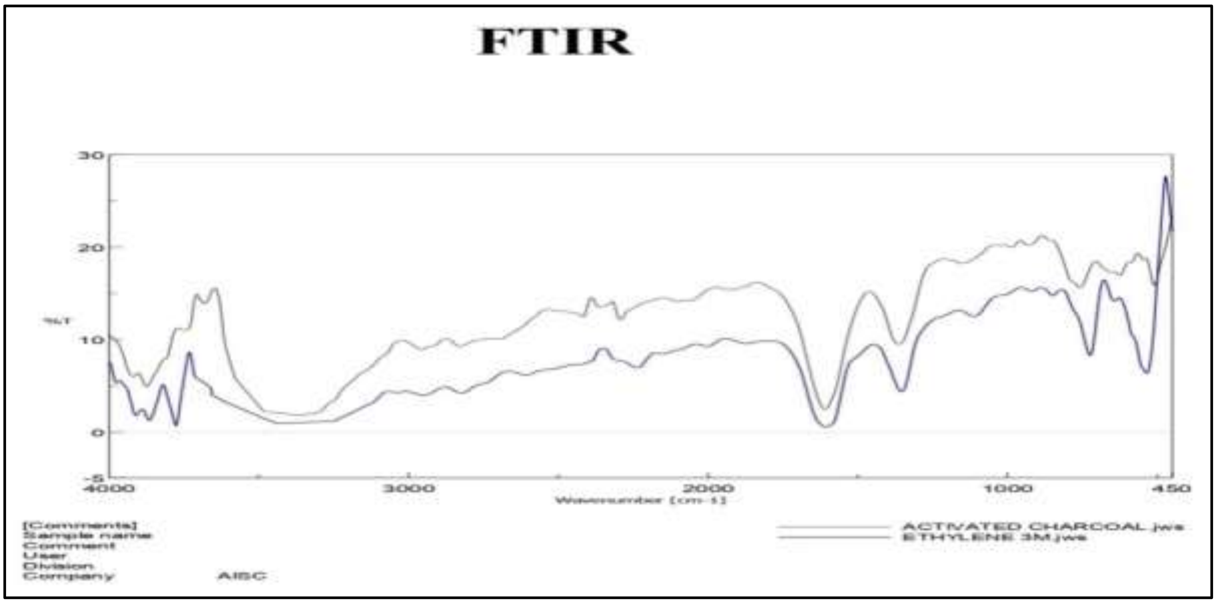


Fig 4: IR spectra of activated charcoal

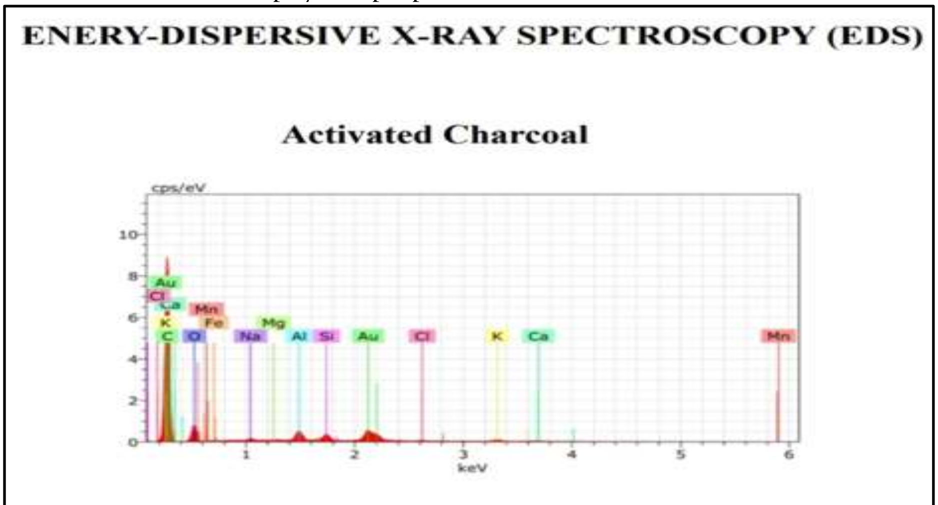
Energy Dispersive X-ray Spectroscopy (EDS) using Analysis of Activated Charcoal

Energy Dispersive X-ray Spectroscopy (EDS) was employed to analyze the elemental composition of activated charcoal, a material frequently used to preserve fruit ripeness, particularly for bananas. The elemental signals obtained from the EDS analysis reveal a strong presence of certain elements that play a significant role in the material's ability to delay ripening.

Carbon (C) - 74.04%: The dominant element in activated charcoal, carbon is essential to its porous structure. The high carbon content reflects the material's basic composition, which is derived from carbon-rich materials such as wood, coconut shells, or coal that undergo pyrolysis. Carbon atoms in activated charcoal are responsible for creating its porous nature, providing a large surface area that can adsorb gases and moisture. The high concentration of carbon could contribute to the ability of activated charcoal to trap ethylene, the hormone responsible for fruit ripening. By adsorbing ethylene, activated charcoal may reduce its concentration around the fruit, thus slowing down the ripening process.

Oxygen (19.09%) is another critical element present in significant quantities in activated charcoal. Oxygen atoms typically bond with carbon atoms to form hydroxyl groups (-OH) on the surface of activated charcoal. These hydroxyl groups can interact with moisture and other volatile compounds, such as water vapor and ethylene, which are crucial in the ripening process. By maintaining the correct moisture balance

around the fruit and limiting the availability of free water, the hydroxyl groups may help retard enzymatic actions involved in ripening, particularly the breakdown of starch into sugar in fruits like bananas.
Aluminum (Al) - 1.72%: The presence of aluminum in activated charcoal, although in much lower quantities compared to carbon and oxygen, may have an influence on its structural properties. Aluminum, a metal with a relatively high affinity for oxygen, could contribute to the material's stability and its capacity to adsorb various substances, including moisture and volatile gases like ethylene. The aluminum content may also indicate traces of minerals or impurities present in the source material from which the charcoal was derived. Silicon (1.16%) is often found in natural substances like clays and sands, and its presence in activated charcoal could be indicative of its derivation from certain plant materials. Silicon's role in the context of activated charcoal may relate to its effect on the material's texture and surface characteristics, enhancing its adsorption capabilities. It may also contribute to the overall stability of the activated charcoal in its application as a ripening delay agent. Potassium (K) (1.08%) an essential nutrient for plant growth, is found in relatively small amounts in activated charcoal. Its presence in the structure may suggest that the charcoal has been derived from plant-based materials, such as wood or coconut shells, which naturally contain potassium. While potassium is not directly responsible for delaying fruit ripening, its presence could enhance the overall stability and durability of the activated charcoal, ensuring its long-term efficacy in maintaining fruit freshness.
Iron (Fe) and Calcium (Ca) - Trace amounts: The low levels of iron and calcium detected in the EDS analysis are likely due to residual traces from the source material or the processing of activated charcoal. These elements, in such small quantities, are unlikely to significantly affect the ripening delay mechanism but could contribute to the overall physical properties of the charcoal.



Spectrum: OBJECT1 568

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
C	6	K-series	74.09	74.09	81.17	9.03
O	8	K-series	19.97	19.97	16.43	3.25
Al	13	K-series	1.72	1.72	0.84	0.12
Si	14	K-series	1.16	1.16	0.54	0.08
K	19	K-series	1.08	1.08	0.36	0.08
Fe	26	K-series	0.90	0.90	0.21	0.09
Ca	20	K-series	0.47	0.47	0.15	0.06
Na	11	K-series	0.32	0.32	0.18	0.06
Cl	17	K-series	0.14	0.14	0.05	0.04
Mg	12	K-series	0.08	0.08	0.04	0.03
Mn	25	K-series	0.08	0.08	0.02	0.04
Au	79	M-series	0.00	0.00	0.00	0.00
		Total:	100.00	100.00	100.00	

Fig 5: EDS of activated charcoal

The elemental makeup of activated charcoal is highlighted by the EDS analysis, which identifies important components that support the charcoal's ability to postpone fruit ripening. Important elements in the material's capacity to interact with moisture and volatile substances like ethylene are its high carbon content and the presence of oxygen in the form of hydroxyl groups. Given that bananas are quite sensitive to ethylene, these interactions are probably going to be crucial in slowing down the ripening process.
The porous nature of activated charcoal creates the perfect conditions for retaining moisture and ethylene gas, which stops these elements from quickening the ripening-promoting enzymatic activities. A crucial component of fruit ripening, activated charcoal slows down the conversion of starches into sugars by preserving a regulated environment surrounding the fruit. Additional components like silicon, potassium,

and aluminium may help maintain the charcoal's general stability and structural integrity and guarantee its ongoing efficacy as a ripening inhibitor.

CONCLUSION

According to the study's findings, using an ethylene absorber to store bananas might lessen weight loss and surface colour changes that occur during storage and transit. Additionally, fruits kept with an ethylene absorber showed a reduction in post-harvest deterioration. Cold storage and an ethylene absorber together may be able to preserve the commodity's quality throughout storage. These investigations make it abundantly evident that, in order to guarantee optimal shelf life at a reasonable cost, ethylene absorber filters with activated charcoal coated with potassium permanganate should be employed in all climacteric fruit storage facilities.

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