Metal Organic Frameworks as Ripening Controller in Fruits and Vegetables

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Controlling the ripening of fresh fruits and vegetables (especially climatic fruits) during storage and transportation is very difficult and important to maintain the required quality. Developing packaging material for climatic fruits is a major challenge faced by researchers because of its quick ripening nature. It is seen that ethylene can be used as a regulator in this situation However, because of safety issues, ethylene cannot be applied directly to climatic fruits. A MOFs was developed by Zhang, et al. (2016) for encapsulation ethylene and its controlled release for ripening at the required stage. MOF functionalities suggest a potential for application in MAP systems such as scavenging or releasing biologically active volatiles in packages of fresh produce (Fruits and vegetables).

What are metal organic frameworks (MOFs)?

Metal-organic frameworks (MOFs) are a class of porous polymeric materials. They are made up of organic bridge ligands linked together with metal ions such as Ca, Mg. This creates an open crystalline framework with stable porosity. MOFs have large surface area in a small volume and are highly porous. The surface areas of typical MOFs range from 1000 to 10,000 m^2/g (size of a football field). Commonly used metal ions for the fabrication of chemically stable MOFs are aluminum, iron, zirconium, titanium, copper, and zinc. Commonly used Organic linkers such as Potassium chloride, Fumaric acid, Isophthalic acid.

Application of metal organic frameworks as ripening controller in fruits and vegetables

Ethylene gas was captured by copper terephthalate MOFs (CuTPA) with 0.39 cm^3g^{-1} porosity. CuTPA was synthesized by the solvothermal synthesis method using methanol as a reactive solvent. The study identified that 654 µL of ethylene was

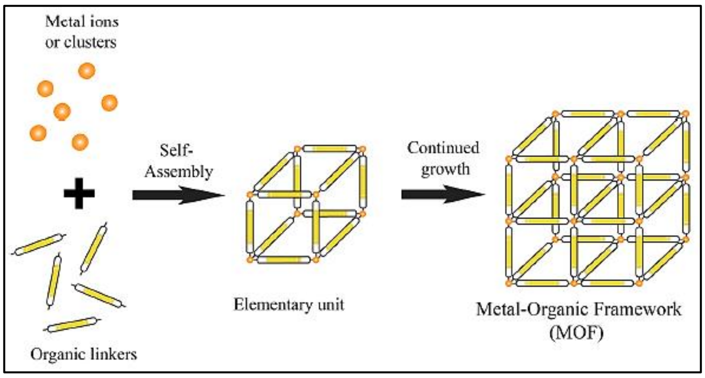

Fig 1: Metal Organic Framework (MOF) Structure

absorbed and released by 50 mg of MOFs, which created an atmosphere enriched with adequate ethylene to control fruit ripening but also a safe level of ethylene (<27,000 µL L^{-1}) was maintained. More significantly, reduction in tissue firmness and ripening related color change acceleration was noticed by using MOF-ethylene treatment. Whereas, on the other case, selective adsorption and desorption of required chemicals which are responsible for ripening is done by MOFs due to their potential utility in the assortment of chemicals and unique porous structure. Since MOFs are formed from matrix materials and functional species, matrix materials allow MOFs to recover and reuse by enhancing the formability of MOFs materials (Li & Huo, 2015). Chopra's team (2017) filled polyolefin bags with BasoliteC300 and added the bags to banana packaging. Ethylene-induced banana ripening due to the ethylene bound to the C300 demonstrates that releasing volatile compounds from an MOF is feasible for practical applications. In a proof-of-concept, it was identified that Basolite C300 exhibited a lofty performance for ripening of produce as an ethylene releasing agent with high-water content in the packaging headspace. On the other hand, bound 1-MCP (17.6% w/w) was not released by the exposure of humidity due to its highest affinity towards Basolite C300. Therefore, active packaging of fruits and vegetables can be regulated for repining by encapsulating ethylene in Basolite C300, so that interference from 1-MCP is minimized via compound removal from package headspace. Basolite C300 is also called MOF-199, and it is a copper-based ultra microporous structure with blue cubic crystals synthesized by the electrochemical method (Van Assche et al., 2012). Basolite A520 is an aluminium-based metal-organic framework which is synthesized by a microwave-assisted technique of MOFs synthesis. The outcome suggested that MOFs encapsulated ethylene can be used in the post-harvest application to maintain the quality of climatic fruits at the consumer level. Many other adsorbent methods are used in food packaging and are the basis for the advancement in the field of food packaging technologies. Convential adsorbents, such as activated charcoal and silica gels mostly used for moisture control (Mehyar & Han, 2011). It has been revealed that zeolites and MOFs have the potential for selective desorption and adsorption of bioactive compounds. These two materials signify a growing class of advanced bioactive adsorbent (ABAs) used for the active packaging of light processed produce. Yan Zhang *et al.*, (2023) team studied on MOFs to adsorb ethylene for fresh produce active packaging. The MOFs was evaluated at two levels. The first evaluation was at the MOF powder level, where the ethylene adsorption capacities of eight commercial MOF powders were measured using gas chromatography (GC). As a result, Mg formate MOF (MgF) and Al (OH) fumarate MOF (AlF) were found to have much higher ethylene adsorption capacities than the other six MOFs. Overall, MgF was the best ethylene adsorber due to its stable ethylene adsorption under various temperatures, relative humidities, and ethylene concentrations. The second evaluation was at the packaging film level, where MgF powder was embedded into three different packaging films. The results showed that MgF-embedded LDPE film had higher ethylene adsorption than MgF-embedded PLA and PVA films. Furthermore, a bio-efficacy study confirmed that MgF-embedded LDPE film could effectively delay banana ripening and extended their shelf life. In conclusion, this study indicates that MgF has promising potential as an ethylene adsorber for shelf-life extension of bananas and probably other fresh produce.

Advantages of Metal Organic Frameworks (MOFs)

- MOFs are their large specific surface area, huge porosity, and easy adjustment of pore size and shape from microporous to mesoporous scale, which can lead to high extraction efficiency.
- Better water stability.
- Different metal ions and diverse organic ligands make MOFs structurally diverse and therefore have the potential for selective adsorption.

Disadvantages of Metal Organic Frameworks (MOFs)

- Adaptation of MOF-based materials as efficient electrocatalysts has been generally hampered by low electronic conductivity, limited accessibility of active sites, and insufficient chemical stability.

Conclusions

MOFs' potential to be embedded in packaging films as ethylene adsorbers to control ripening and extend the shelf life of fruits and vegetables during distribution. However, there are still big challenges in scaling up their use in large-scale ripening controller food packaging application: the selectivity of separating similar gas molecules through MOFs is limited; the fabrication of MOF-based packaging materials is difficult to integrate into large-scale industry methods and metal ions and organic ligand functional groups are toxic, which requires more safety characterization for direct application in food packaging.

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