# New study shows how carbonated water can be used to tune properties of hydrogels for various uses

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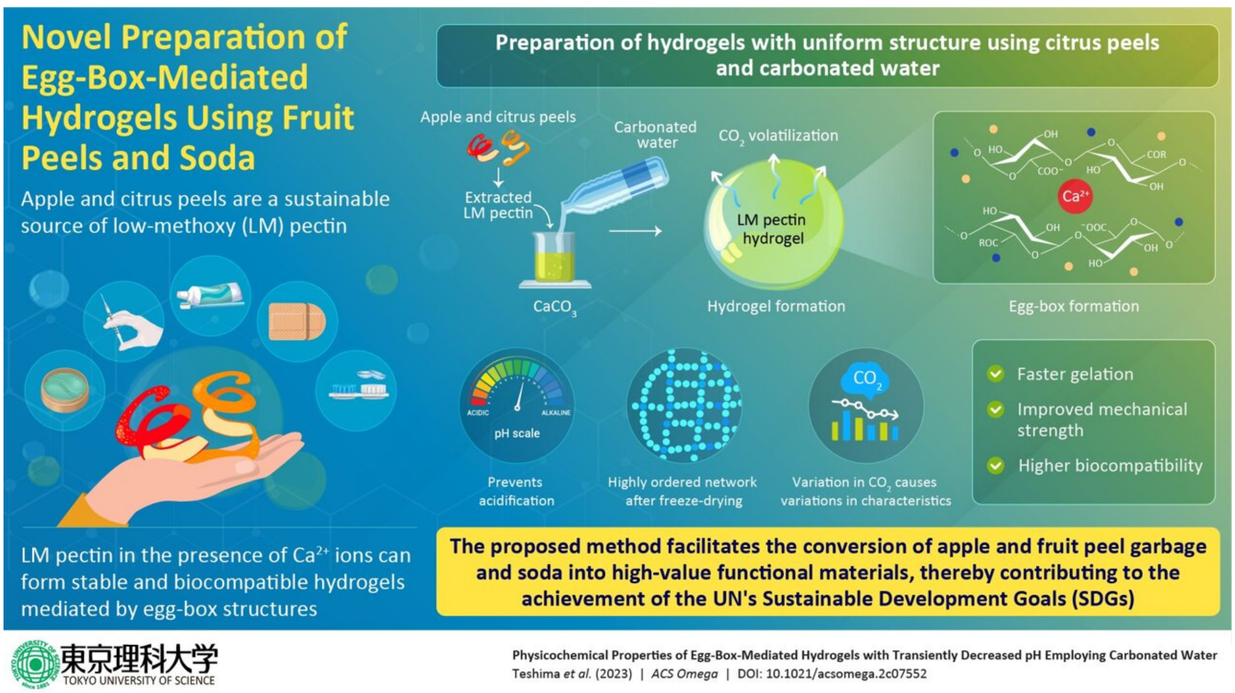


The novel hydrogel uses carbonated water as a source of carbon dioxide and fruit peels as a source of low-methoxy pectin, resulting in high strength, uniform mesh structure, and high biocompatibility. Credit: Ryota Teshima from Tokyo University of Science

Low-methoxy (LM) pectin gels have gained momentum in tissue engineering and drug delivery in recent years due to their excellent biocompatibility. LM pectin forms stable hydrogels by forming supramolecular assemblies with egg-box structures in the presence of divalent ions like $Ca^{2+}$, generally provided by a calcium chloride ($CaCl_2$) solution or calcium carbonate ($CaCO_3$). In particular, the use of $CaCO_3$ enables the preparation of LM pectin gels with controlled shape.

Previous research has shown that minute changes in hydrogel synthesis precursor parameters can majorly impact the hydrogel properties and their applications. For instance, decreasing the pH or acidifying the precursor accelerates the gelation rate and increases the mechanical strength of LM pectin hydrogels. $CO_2$ is a popular acidic agent because it can decrease pH and be easily removed from the system after gelation.

However, despite $CO_2$ being a promising acidic agent, a precise understanding of its effects on hydrogel synthesis and properties is poorly understood.

A group of scientists from Japan, led by Mr. Ryota Teshima, a Master's student from Tokyo University of Science (TUS), decided to fill this gap. To do so, they prepared LM pectin/$CaCO_3$ hydrogels using the standard method and under controlled thermodynamic conditions with carbonated water as the source of $CO_2$.

The research team also included Dr. Shigehito Osawa (currently at Tokyo Women's Medical University), and Dr. Yayoi Kawano, Prof. Takehisa Hanawa, Prof. Akihiko Kikuchi, and Prof. Hidenori Otsuka from TUS. Their research was published in *ACS Omega*.

Explaining the reasoning behind this approach, Mr. Teshima says, "We chose carbonated water as the acidic agent for gelation because conventional methods would require high-pressure conditions to ensure proper supply of $CO_2$ to the hydrogel precursor. Instead, using carbonated water allowed us to supply carbonate ions and $CO_2$ to the hydrogel mixture and trigger gelation under ambient pressure and temperature conditions."

The team simultaneously prepared two LM pectin/$CaCO_3$ hydrogels—one with added carbonated water and the other without. They observed that the one with carbonated water underwent faster gelation and showed increased mechanical strength compared to the one without.

These improvements could arise from the lower pH of carbonated water enhancing the solubility of $CaCO_3$, which further increases the availability of free $Ca^{2+}$ ions. More $Ca^{2+}$ means better cross-linking between pectin polymers, quicker gelation, and more robust hydrogels.

After the hydrogel formation, carbonated water/$CO_2$ was volatilized from the surface in contact with the atmosphere. The team found that post-$CO_2$ escape, the pH of the final hydrogel was higher than the hydrogel prepared without carbonated water. The team suggested this could be because many carboxy groups were consumed during cross-linking. with $Ca^{2+}$ and the acidic component, $CO_2$, was completely volatilized from the hydrogels after gelation.

The team further prepared aerogels by freeze-drying the hydrogels. They found highly ordered networks of elongated porosity in those prepared through the carbonated water route, suggesting that the $CO_2$ from carbonated water could induce intrinsic structural changes in the hydrogels.

The researchers also prepared hydrogels with different amounts of $CO_2$ in the carbonated water to demonstrate that the pH and strength of LM pectin hydrogels can be tuned in this manner. The insights from this study can prove helpful when fabricating functional hydrogels with tailored properties.

This research contributes to the United Nations' sustainable development goals (SDGs), as the LM pectin was primarily derived from food waste, such as apple and citrus fruits. "Every year, 2.5 billion tons of food is wasted worldwide, which includes vegetables and fruits that are discarded without ever reaching the market because of quality issues. We believe that the promising results of our study will encourage other researchers to use items thrown out as food waste as raw materials for their scientific ventures," concludes Mr. Teshima.

**More information:** Ryota Teshima et al, Physicochemical Properties of Egg-Box-Mediated Hydrogels with Transiently Decreased pH Employing Carbonated Water, *ACS Omega* (2023). DOI: 10.1021/acsomega.2c07552

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