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Editorial: Recent knowledge on the applications of molecular hydrogen in plant physiology, crop production, and food processing

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Editorial on the Research Topic
Recent knowledge on the applications of molecular hydrogen in plant physiology, crop production, and food processing

Molecular hydrogen (H_2) was first produced in the early 16th century, and hydrogen was formally identified as an element by Cavendish in 1766. The effects of H_2 on biological systems were relatively quickly studied by several people including Priestley, Lavoisier, Cavallo and Davy (Hancock and LeBaron, 2023). Although such research has been sporadic over the last two hundred years (LeBaron et al., 2023), there is now a growing realisation that treatment with hydrogen gas can have significant beneficial effects. This is particularly true in the biomedical arena where it has been mooted as a therapy for a range of medical conditions (Ohta, 2014; Ge et al., 2017), including cancer (Noor et al., 2023) and neurological disorders (Ramanathan et al., 2023). Of relevance here, such work shows that H_2 is not toxic and well tolerated by humans.

The action of H_2 in cells involves the reduction of reactive compounds such as hydroxyl radicals (Ohsawa et al., 2007) and an increase in antioxidant capacity, both of which lead to reduced oxidative stress (LeBaron et al., 2019), as well as other potential mechanisms (Hancock et al., 2022). Therefore, it is not surprising that similar mechanisms take place in plant cells. H_2 has been shown to have favourable effects on seed germination (Xu et al., 2013), plant growth (Wu et al., 2020) and stress tolerance, such as drought (Islam et al., 2023). H_2 can also be used to prolong the vase life of flowers (Ren et al., 2017) and for postharvest storage of fruits (Hu et al., 2014; Alwazeer and Özkan, 2022) and vegetables (Ali et al., 2023). Many of the studies using H_2 treatments on plants focus on growth under stress conditions, which in many ways parallels findings observed in animals. Therefore, a

Research Topic exploring the potential benefits of H_2 in plant and food science is both timely and relevant.

This Research Topic attracted four articles. One of the issues when researchers are reporting their data is that they do not measure H_2 concentrations in solution. This is important if standardised methodologies for treatment of plants and plant/food materials are ever going to be developed and adopted. One method which is sometimes used to estimate H_2 concentrations is to measure the oxidation reduction potential (ORP) and using this to estimate the H_2 concentration with the Nernst equation. The first paper in the SI by LeBaron and Sharpe demonstrated through *in silico* analysis that ORP is unreliable to estimate or compare H_2 concentrations in aqueous solutions. The study suggested that more accurate methods should be employed, as small deviations in pH, temperature, and normal ORP fluctuations can significantly affect the predicted H_2 concentrations, often exceeding the range used in most studies.

In an original research article, Dong et al. looked at the traditional Chinese herb *Gastrodia elata*, which is used for a range of remedies, including headaches, convulsions and epilepsy (Wu et al., 2023). Their focus was on the effects of hydrogen-rich water (HRW) on the herb that had been freshly cut and was in 4°C storage. It was found that HRW decreased weight loss of material, and reduced the generation of reactive oxygen species (ROS), whilst increasing antioxidant activity. The lowering of activities of key metabolic enzymes such as cytochrome oxidase, succinate dehydrogenase and H^+-ATPase was also noted. Overall, the use of HRW was beneficial during the storage of this herb.

Alwazeer et al. looked at the use of H_2 in the extraction of phytochemicals from plant materials. They infused H_2 into various solvents (water, ethanol, methanol) before their use in extraction from lemon peels. Compounds such as phenolics, flavonoids, and anthocyanins were extracted using solvents with and without H_2. The addition of H_2 into all the solvents significantly improved the extraction of all phytochemical groups studied with the highest levels found for H_2-rich methanol. It was therefore concluded that addition of H_2 to such processes was worth considering, which is supported by similar studies (for example, Ceylan et al., 2023; Alwazeer et al., 2023a; Alwazeer et al., 2023b; Alwazeer and Elnasanelkasim, 2023; Alwazeer et al., 2023c).

Finally, a paper by Alwazeer et al. featuring several members of the editorial team, provides a comprehensive review of the Research Topic's focus. This review covers the application of H_2 in agricultural practices, food safety, processing and packaging, and the valorisation of food waste. It further explores the bioactivity of H_2, along with the regulations, toxicity, and safety considerations associated with its use. The review concludes with a section on the current status of research and future perspectives for the use of H_2 in plant growth, food science, and production practices. It is hoped that this will inspire further research endeavours in this area.

Considering the final paper in the SI, it is evident that this topic has a bright future. The application of H_2 to plants at a variety of stages is relatively easy and cheap. Often treatments involving the creation of a HRW which can be used as a watering medium or sprayed onto plant materials, as well as a washing material for treating various foods. In enclosed spaces, H_2 can be used directly as a gas, and both methods leave no toxic byproducts. H_2 has been used safely in deep sea diving for approximately 80 years (Bjurstedt and Severin, 1948). As H_2 gas becomes used more, for example, in transport (Singh et al., 2015), it is expected to become cheaper and more accessible, enhancing its cost-benefit profile. The potential applications of H_2 across various plant developmental stages and stress conditions offer significant promise for improving food security, plant physiology, crop yields, and food storage and processing.

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Conflict of interest

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