

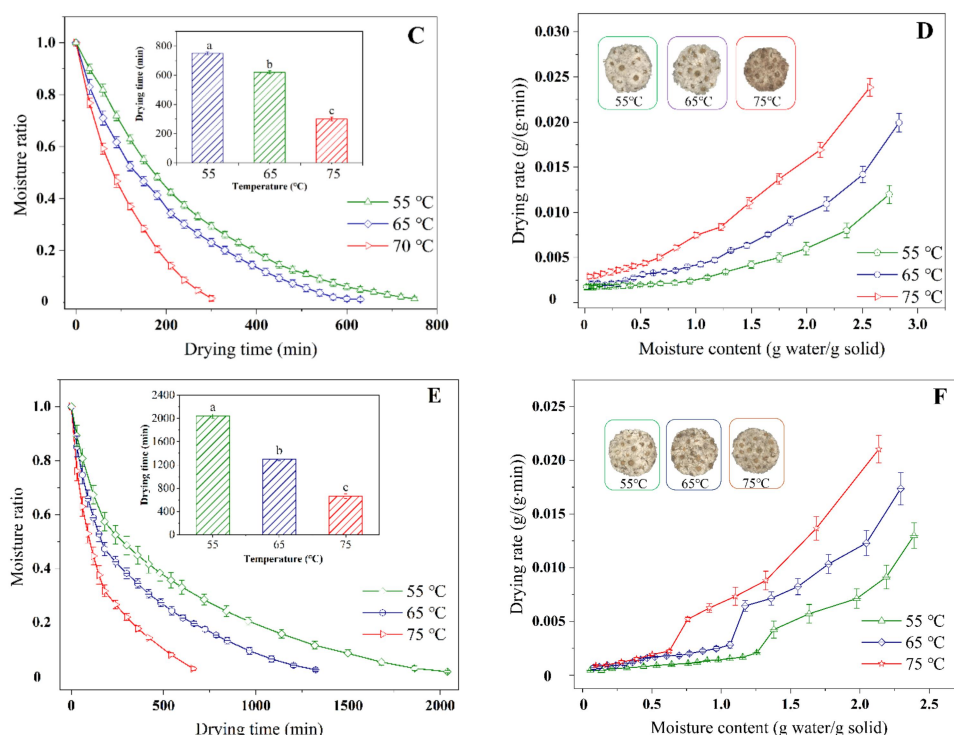


Figure 2 Moisture ratio (A,C,E) and drying rate (B,D,F) of chrysanthemum cakes under different drying methods (Adopted from Xu et al., 2022a)

Image caption: (A, B): Hot air drying (HAD); (C, D): Combined infrared and hot air drying (IR-HAD); (E, F): Sequential IR-HAD and HAD (IR-HAD+HAD), different lowercase letters reveal significant differences ($p < 0.05$) (Adopted from Xu et al., 2022a)

4.3 Effects of microwave drying and vacuum freeze-drying on the quality of Hangbaiju

Microwave drying and vacuum freeze-drying represent two contrasting technical routes for improving Hangbaiju quality: one emphasizes rapid dehydration and enzyme inactivation, and the other emphasizes low-temperature preservation. In medicinal chrysanthemum, flavone and chlorogenic acid contents increased significantly with increasing microwave power, although amino acid content decreased significantly under microwave treatment (Shi et al., 2017). Considering efficiency and energy consumption, microwave drying was identified as the most suitable method among four tested methods for retaining higher flavone, vitamin C, and soluble sugar contents. In a direct comparison of drying methods, microwave treatment for 30 s combined with 75 °C hot-air drying was the most effective at preserving biologically active compounds and produced higher antioxidant capacity and stronger acetylcholinesterase inhibition (Wang et al., 2019). Another kinetics study similarly found that mild microwave-assisted hot-air treatment retained higher total phenolics, total flavonoids, and seven monomeric compounds with only limited conformational change (Wang et al., 2018).

Vacuum freeze-drying generally performs best for preserving physical structure, appearance, and many bioactive compounds, but its cost and drying time are major drawbacks. Freeze-drying improves the bioactive composition and physical structure of chrysanthemum products, although it is often considered economically unrealistic for seasonal herbs because of high energy consumption and equipment investment (Xu et al., 2022a). In Taihang chrysanthemum, freeze-drying maintained phenylpropanoid-rich bioactive compounds, gave superior antioxidant activity, and also supported stronger antibacterial and pancreatic lipase inhibitory activities (Fan et al., 2024). Evidence from other dried floral materials points in the same direction: vacuum freeze-dried petals showed the best appearance, highest bioactive compounds and antioxidant activity, and the best sensory similarity to fresh infusions (Suo et al., 2023). Freeze-dried samples also tend to preserve lighter color and heat-sensitive carotenoids better than convective drying, although the retention of phenolics can still depend on the specific plant matrix (Chua et al., 2019). Therefore, for Hangbaiju, microwave-assisted drying is more advantageous when processing efficiency and active-component retention must be balanced, whereas vacuum freeze-drying is more suitable