INFRARED RADIATION AND ULTRASOUND FOR SUNFLOWER SEED DRYING: EVIDENCE SYNTHESIS AND AN UNMET OPPORTUNITY FOR HYBRID PROCESSING

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Abstract

Drying is a critical postharvest operation for sunflower seeds because excessive temperature and long exposure times can reduce seed quality, while insufficient drying compromises storage stability. Recent studies suggest that ultrasound-assisted convective drying (US-CD) and infrared drying with vibration (IR-V) can intensify heat and mass transfer relative to conventional hot-air approaches. In the most directly relevant sunflower-seed study on US-CD, airborne ultrasound increased effective moisture diffusivity by up to 44.84% and reduced drying time and energy consumption by up to 40.85% and 32.95%, respectively; the optimized condition shifted from a purely convective optimum of 50.74 °C, 2 m/s to 40.64 °C, 2 m/s, 3.932 W/g ultrasound [1]. A separate IR-V engineering study reported an optimized regime for sunflower seeds using 1.5–3.0 μm IR wavelength, 15 mm bed depth, and 5 kW/m² incident heat-flux density with emitters positioned 25 mm above the layer, achieving a reported drying time of ~11 min [2]. Across the screened literature, no peer-reviewed study was identified that simultaneously applies IR and ultrasound to sunflower seeds, despite

the fact that ultrasound–infrared coupling has been explored in other plant materials, suggesting a plausible (but untested) synergy for oilseeds [10].

Keywords: sunflower seed; infrared drying; ultrasound-assisted drying; vibration; energy efficiency; product quality

1. Background and rationale

Conventional hot-air drying can be slow and energy intensive, and elevated temperatures may accelerate sunflower seed deterioration and reduce vigor [9]. Experimental evidence indicates that drying temperatures above approximately **40 °C** may reduce vigor and increase damage under certain conditions, highlighting the need for intensification methods that reduce thermal load while maintaining drying performance [9].

Two intensification routes are particularly relevant:

- **Ultrasound-assisted convective drying (US-CD):** Ultrasound can reduce internal and external mass-transfer resistance (e.g., "sponge/vibration" effects and microstructural changes), often shortening drying time and lowering energy demand, as also summarised in review literature [1,4,5,8].
- **Infrared drying (IR), especially with mixing/vibration:** Infrared radiation can deliver high heat-flux and rapid moisture removal; vibration/mixing can improve uniformity in granular beds and reduce local overheating risk [6,7].

2. Methods (as reported and edited for academic clarity)

A semantic search was performed using the query "Drying sunflower seeds using infrared light and ultrasound" across the Elicit search engine corpus (Semantic Scholar + OpenAlex). The 50 most relevant records were screened using the following eligibility logic:

- sunflower seeds as the primary material;
- IR drying, ultrasound-assisted drying, or their combination;
- controlled experimental/engineering conditions;
- quantitative outcomes (time, energy, diffusivity, quality metrics);
- drying as the main focus and supported by empirical data.

Data were extracted into: technology configuration, operating parameters, performance outcomes, quality impacts, optimization results, comparative baseline, and study-design descriptors.

3. Results

3.1 Included evidence base

Your screening yields two directly eligible studies addressing sunflower seeds with (I) ultrasound-supported convective drying and (II) IR drying in a vibrating/engineered configuration [1,2].

Table 1. Characteristics of the core included studies

Study	*Technology*	*Configuration*	*Key reported specs*
Dibagar et al., 2020	US-assisted convective drying	Hybrid chamber; airborne ultrasound with indirect transmission	Ultrasound power reported in W/g; optimization reported [1]
Zozulyak, 2023	IR drying with vibration/engineering focus	Vibrating bed/tray concept with IR emitters	1.5–3.0 μm; 5 kW/m²; 15 mm layer; 25 mm emitter height; ~11 min [2]

Note: Related IR-vibratory tray work for sunflower seeds is also reported in engineering literature (e.g., vibrating tray IR dryer analyses), supporting the plausibility of vibration as a mixing/intensification mechanism even when not classified as "combined IR-V" in the same way across papers [3].

3.2 Ultrasound-assisted convective drying (sunflower seeds)

Dibagar et al. quantified clear performance gains relative to convective drying alone: effective moisture diffusivity increased by up to 44.84%, while drying time, energy consumption, and total color change decreased by up to 40.85%, 32.95%, and 44.56%, respectively, under reported combined settings (e.g., 35 °C, 3.5 m/s, 2.4 W/g). Optimization shifted the best convective condition from 50.74 °C and 2 m/s to 40.64 °C, 2 m/s, and 3.932 W/g ultrasound, achieving additional reductions in drying time (19.89%) and energy consumption (19.32%) at that optimized point [1]. These outcomes are consistent with wider evidence that ultrasound can intensify drying kinetics and allow operation at lower temperatures, supporting potential quality protection alongside improved efficiency [4,5,8]. [4,5,8].

3.3 Infrared drying with vibration/engineered mixing (sunflower seeds)

The IR-focused study reports an optimized sunflower-seed regime at **1.5–3.0 µm** wavelength, **5 kW/m²** incident heat-flux density, **15 mm** seed-layer height, and **25 mm** emitter distance, achieving a reported drying time of **~11 minutes** under those settings [2]. The same source argues that conventional grain dryers (mine/drum types) may be poorly matched to sunflower seeds and may exhibit low single-pass moisture removal, localized overheating, non-uniform final moisture, and higher fire hazard, motivating alternative designs such as vibrating beds/trays [2]. Independent vibrating-tray IR dryer analyses similarly underline that seed rotation and monolayer-style movement can improve irradiation uniformity and reduce overheating risk [3]. This is consistent with IR-drying reviews: IR can strongly intensify drying, but excessive power or too small emitter distance can overheat product; therefore, layer depth, distance, and mixing are critical design variables [6,7].

4. Synthesis and research gap

Across the screened sunflower-seed literature, US-CD appears particularly attractive where energy efficiency and appearance-related quality (e.g., color change reduction) are primary objectives. In contrast, IR-V targets extremely short residence times and better bed uniformity via mixing/vibration, aligning with high-throughput oilseed operations—although reporting of energy metrics may be inconsistent across engineering papers. Within the screened set, no study was identified that applies infrared heating and ultrasound simultaneously to sunflower seeds.

However, ultrasound–infrared coupling has been investigated for other plant materials, indicating the approach is technically feasible and may offer synergistic intensification worth testing for sunflower seeds [2,3,6,7].

5. Conclusion

The best available sunflower-seed evidence indicates that (I) **airborne ultrasound assistance** can reduce drying time and energy consumption while improving selected quality indicators, and (II) **infrared drying with vibration/mixing concepts** can achieve very rapid drying under optimized geometric and heat-flux conditions[1,2]. A well-designed experimental program that couples **IR + ultrasound** (e.g., IR as primary heat input + airborne ultrasound to reduce mass-transfer resistance) represents a clear and defensible research opportunity [4–7,10].

References

1. Dibagar N., Kowalski S.J., Chayjan R.A., Figiel A. *Accelerated convective drying of sunflower seeds by high-power ultrasound: Experimental*

assessment and optimization approach. Food and Bioproducts Processing, 2020. ScienceDirect

2. Zozulyak I. *Simulation of the process of vibrating sunflower drying.* Engineering, Energy, Transport AIC, 2023. ResearchGate
3. Bandura V. et al. *Case study: Dynamics of sunflower seed movement in the vibrating tray of the infrared dryer and its influence on the drying process.* Agraarteadus / Journal of Agricultural Science, 2021. ir.vtei.edu.ua
4. Musielak G., Mierzwa D., Kroehnke J. *Food drying enhancement by ultrasound – A review.* Trends in Food Science & Technology, 2016. ScienceDirect
5. Huang D. et al. *Ultrasound in Food Drying Technology* (review), 2020. ScienceDirect
6. Huang D. et al. *Application of infrared radiation in the drying of food products* (review), 2021. ScienceDirect
7. Salehi F. *Recent Applications and Potential of Infrared Dryer Systems for Drying Various Agricultural Products: A Review.* International Journal of Fruit Science, 2020. tandfonline.com
8. Wu J. et al. *Recent advances in ultrasound-coupled drying for improving the quality of fruits and vegetables: A review.* International Journal of Food Science & Technology, 2022. ifst.onlinelibrary.wiley.com
9. Huang Y. et al. *High drying temperature accelerates sunflower seed deterioration…* Frontiers in Plant Science, 2021. Frontiers
10. Guo Y. et al. *Effects of power ultrasound enhancement on infrared drying…* Journal of Food Engineering (or related outlet), 2020.