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Paper

PAPER

LITERATURE STUDY: ADVANCES IN DRYING AND RELATED PROCESSING METHODS OF SUNFLOWER SEEDS AND CEREAL PRODUCTS

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Abstract

Village farm grain products in the field again work from the harvest next main from processes one is considered . From the harvest then cereals humidity in moderation not to reduce as a result mold and other reasons due to a large amount loss and grain quality to decrease take It comes. Like this of circumstances prevent in receiving of course drying processes and drying methods are also very important profession will reach . Moisture content of dried grain grain drying system working exit and researchers and grain again work optimal operation of the industry choice for solution doer factor is considered. In the study drying methods deep analysis done is, grain drying the most effective and energy effective methods illuminating passed.

Key words: Sunflower, grain, seed grain, moisture, grain dryer, convective drying.

Introduction

Sunflower (*Helianthus annual* L.) seeds high good quality It is valued for its oil, protein-rich food, and various bioactive compounds. Drying processes not only sunflower seeds maybe other grains from the harvest for next important process This process is used to process grain products. safe storage for humidity reduction, mold and pests with damage prevent to take and grain products again work processes facilitates. Traditional convective drying often high temperature and it takes a long time, this food substances deterioration, quality change and energy spending increase to the surface comes. Last research ultrasonic convective drying (UACD), microwave convective drying (MCD), pulsed electric fields (PEF), electromagnetic induction at low pressure (EMILP) and sun using vibrating in bed drying (SOD) - heat transfer, energy efficiency increase such as hybrid and unconventional approaches This review synthesizes findings from 2009-2024, examining methodologies, modeling strategies, qualitative results, and future research directions compares.

Materials and Methods

Convective and hybrid drying methods.

Ultrasound-assisted convective drying (UACD)

• **Mechanism:** High- power ultrasound on the surface of the seed cavitation and micro the flow brought releases moisture spread and convective heat conductivity increases.

• **Home findings:** Debugger and etc. 44.8 % of the effective moisture diffusion at 35 °C, 3.5 m/s air velocity and 2.4 W/g sonication power [1] increase (Deff) and drying showed a 40% reduction in time and a DE color change. Sonication lowered the optimal convective temperature from 50.7 °C to 40.6 °C, reducing energy consumption by 19.3% [1].

• **Advantages:**

o Drying time reduced by up to 70

o Energy savings up to 32

o Flexible integration with existing convective systems.

• **Limitations:**

o Ultrasound in bulk materials one kind not been distribution.

o High elementary equipment and setup costs.

o batch mass and air temperature.

Microwave Convective Drying (MCD)

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• **Mechanism:** Volumetric microwave heating thermal reduces gradients; convective air flow steamed humidity take throws.

• **Home findings :** Dervish and others. 1.73×10^{-7} and between 4.76×10^{-7} m^2/s Def about reported and validated the Page model for drying kinetics. 300 W microwave in power energy efficiency the most high to the top came out, to himself and the specific energy consumption was minimized [3]. Microwave power and further optimization of hybrid airspeed control for potential showed.

• **Advantages:**

o Drying time reduced from 12.5 minutes to 3.5 minutes.

o Traditional to methods 65-70

o nutritional and sensory qualities.

• **Limitations:**

o kind not been heating and hot spots danger.

o High power requirements and special equipment.

o Some seed in types limited application.

Electromagnetic induction at low pressure (EMI LP)

• **Mechanism:** Induction heating under vacuum (e.g. 50 mbar) lowers the boiling point of water, reduces oxidative damage, and preserves protein structure.

• **Key findings:** Ortiz Hernandez et al. reported 99.1% protein retention and >66% germination after 0.5 h at 65 °C and 50 mbar, while thermosolar drying showed 94.9% protein and 24% germination after 4 h [4]. Moisture removal was 2.5 times faster than thermosolar drying and the volumetric expansion coefficient was 5% higher [12].

• **Advantages:**

o Fast humidity loss (heats to 65 ° C in 5 minutes).

o Seeds vitality and excellent preservation of nutrients.

o Oxidation is reduced in low oxygen conditions.

• **Limitations:**

o High capital and operating costs for vacuum and induction equipment.

o The probability of uneven distribution of fields.

o Application seed to the characteristics and camera to the design depends.

With the help of the sun vibrating in bed drying (SOD)

• **Mechanism:** vibrating bed (2 Hz) air seeds with the connection increases; solar collectors are recycled renewable the heat provides.

• **Home findings:** Shanmugam and Veerappan 32 kg of seed at 2 Hz achieved 30% thermal efficiency by drying to <10% moisture in 8 hours under vibration. Reflective glazing and insulated coatings improved performance [6,11].

• **Comments:**

o Sun radiation variability reliability impact does.

o Hybrid auxiliary heating (biomass, electric) recommended during low sunlight.

Pretreatment and extraction enhancement

Pulsed electric fields (PEF)

• **Mechanism and Benefits:** Short, high-voltage pulses cell membranes conductive does, humidity and oil diffusion accelerates.

• **Home findings :** Shorstkii and Koshevoi def increased from 9.89×10^{-12} to 1.55×10^{-11} m^2/s and increased oil productivity by 8.1% [15].

• **Future Directions:** Speed and integration with mild thermal pretreatment (thermo PEF) to balance the stability of the compound.

Enzyme-assisted aqueous extraction (EAEP)

• **Mechanism and benefits:** Enzymes hydrolyze cell walls, without solvent residues water in the environment of oil exit makes it easier.

• **Home findings:** Munder and et al . achieved an extraction efficiency of 82.2% and a mass recovery of 93% in a continuous reactor using optimized temperature (50 °C), enzyme loading (1.5% w/v), and pH (7.0) through response surface methodology [16].

• **The concept of sustainability:** at scale enzymes consumption to do economic requires a benefit analysis.

Nourishing and quality storage

Phytochemical and antioxidant stability

• Roasting at 200 °C for 15 minutes maximizes flavor and polyphenol retention [2].

• Heat pump drying at 40 °C and frying at 145 °C for 5 minutes, then vacuum packing and storing at 4 °C tocopherol and phenolic preserves substances for 12 months [5].

• Analytical methods: HPLC and DPPH assays bioactive preservation and decomposition their ways quantitative in terms of determines.

Protein Integrity and Sprouting

• EMI LP drying outperformed other methods, retaining 98% protein and > 66% sprout viability [4].

• With cold plasma and radio frequency processing to give of seeds vitality and phytohormones balance modulation does [17].

Modeling, thermodynamics and safety

Thin-layer drying models

• Common models: Newton, Page, Henderson-Pabis, Logarithmic, Weibull.

• Page model $R^2 > 0.98$ and microwave convective information produces a low RMSE for.

Sorption Isotherms

• Campos et al. evaluated 15 sorption models and found Smith's model to be the most accurate (RMSE = 0.025 g/g) [9].

• Desorption isosteric heat of 1.79-2.67 kJ/kg; Gibbs free energy positive is, moisture by itself the disappearance shows.

Microbial Safety

• Keller et al. achieved a >5 log reduction of Salmonella by drying at ≥51 °C and 30–40

• Thermal UV or Combining with ozone treatment increases safety.

Process integration and industrial implications

• Masalimov and others. Diluted with bed refrigerated microwave conveyor the dryer modeled, optimized power time regimes to minimize costs per dried kilogram [10].

• Life cycle assessment of hybrid systems renewable integration and himself justification deadlines (3.8 years for biomass-solar hybrids) [22].

Emerging technologies

Ultrasonic vacuum microwave hybrid drying

• Vacuum microwave combined ultrasound drying time by 35% reduced the damage by 30% increased and 15% more tocopherols save left; energy consumption decreased by 20% [20]. Infrared Thermography b Control

• Near-infrared imaging enabled dynamic control of air temperature within ±2 °C, reduced humidity CV < 5%, and reduced energy consumption by 12% [21].

Solar Biomass Hybrid LCA

• Experience-scale assessment 45% IG and 25% less operational expenses showed; local fuel prices under 3 .8 year inside himself justifies [22].

In drying IoT and the car study

• IoT with equipped The dryer achieved an accuracy of ±0.5%; automated control reduced drying time by 18% and energy by 10% [23].

Conclusion

Advanced drying and initial processing to give technologies drying speed, energy efficiency and product quality noticeable at the level improves. Future research to the following advantage to give need:

Smart drying systems: IoT for flexible management and the car study with integrated real-time sensors (humidity, temperature, color).

• **Energy integration : carbon Connecting with** solar PV, waste heat recovery and biomass boilers to reduce footprint.

• **scale Increase:** Validation of laboratory results, uniformity assessment and normative to documents compatibility Pilot and industrial tests to ensure.

• **Holistic assessments:** comprehensive techno-economic analyses, life cycle assessments and technology market in segments to master leadership to do sensory evaluation for.

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