DRYING HERBS WITH LESS ENERGY

Tea, spices and other organic matter are preserved by drying. The drying process sometimes consumes considerable amounts of oil, gas and electricity. An absorption process developed at the Zurich University of Applied Sciences (ZHAW) significantly reduces energy consumption. The process enables solar heat or waste heat from industrial processes to be efficiently utilized for energy. The new drying process has a wide range of potential applications, in the food industry or in paint shops, for example.

The agitator of the new drying system ensures that the herbs are dried evenly and that no pockets of moisture remain. Photo: ZHAW

A technical report about the results of a research project in the field of industrial processes, which has been financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Foodaktuell (issue January 2024).

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It's not an everyday occurrence: In the laboratory of a technical university, sitting on a table, are plastic bags full of dried herbs. When opened, a strong mint scent wafts across the room. If there were a tea infuser and hot water, a cup of mint tea would be ready in no time. However, this is no tea house, but the ZHAW campus in the center of Winterthur. A basement houses the laboratory of the Institute of Energy Systems and Fluid Engineering (IEFE). Next to the table with the tea bags is a floor-to-ceiling unit. It is used to dry mint, spices and medicinal plants using an innovative process.

Herb drying is a common preservation process – dry air flow is directed through the material to be dried. Until now, the drying air has usually been supplied using fossil fuels or electricity (heat pump dehumidifiers.) The situation is different with the drying apparatus in Winterthur: Here, air dehumidified by absorption flows through the organic material and absorbs its moisture. The dehumidification of the drying air by absorption has a double advantage: The preparation of the drying air is done without fossil energy and without electricity. What's more, the absorber fluid can be regenerated with industrial waste heat or solar heat and then reused (see text box p. 3 for how it works).

Seventy-five percent less energy

"Our process has great potential to enable the drying of herbs with significantly less energy," says Serena Danesi, who led the SFOE-supported research project at the ZHAW before it was completed in autumn 2023. The final report of the project supports this statement with statistics: Compared to a conventional drying system with a heat pump dehumidifier, the ZHAW laboratory system requires around 75% less electrical energy and reduces the drying time by 50% (the ZHAW team does not take the energy for regenerating the liquid caustic soda into account here, as this is "surplus, free energy.") The absorber liquid (liquid caustic soda) is "easy to handle" and the quality of the dried herbs is "equivalent or higher" than in conventional drying systems, the researchers write in the final project report.

The ZHAW functional model is the product of three years of research. The scientists involved built an initial functional model and arrived at the version available today via various optimizations. One of the central challenges was process control of the absorption liquid, which extracts the water vapor in the absorber from the air stream. Liquid caustic soda is already used in industrial processes, but only in hermetically sealed circuits. The reason for this is that when liquid caustic soda comes into contact with air, it reacts with CO_2 to form sodium carbonate, which precipitates as sediment. This is how the liquid caustic soda is consumed.

Functional model of the ZHAW absorption dryer: The system has a drying area of one square meter. Nettles, apple mint, peppermint and other herbs up to a moisture content of 12% can be dried in it. Photo: ZHAW

Design challenges

In the ZHAW functional model, liquid caustic soda is used for the first time in an open process – in contact with air. However, since the housing of the absorption dryer is sealed, the liquid caustic soda can only react with the volume of air in the dryer. This volume of air is so small that the total amount of liquid caustic soda is not significantly reduced, as the experiments have shown.

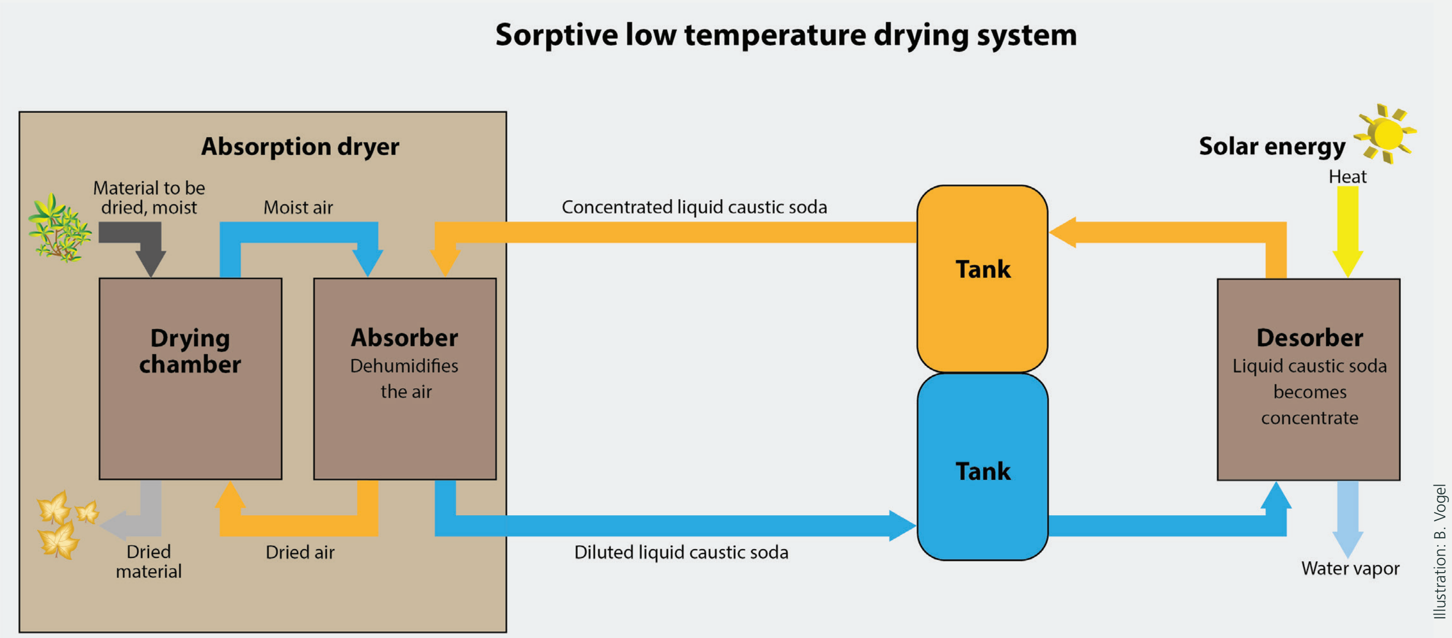
Another challenge in the design of the dryer was to ensure that the material was dried evenly and that no areas of re-

HOW THE ABSORPTION DRYER WORKS

Absorption scrubbers (also known as 'gas scrubbers') are used in industry when a certain substance needs to be removed from a gas stream (e.g. a pollutant from an exhaust gas stream in a flue gas cleaner). For this purpose, an absorbent liquid is used, which absorbs the substance to be removed. This well-known method is now being used by the ZHAW researchers for the first time in a drying process: Liquid caustic soda (sodium hydroxide/NaOH dissolved in water) is used as an absorber fluid. This hygroscopic (water-absorbing) liquid absorbs the water vapor from the airstream that was used for drying. The air freed from water vapor can be returned to the dry material in a cycle and used again for drying.

This is interesting from an energy point of view. The process that takes place in the absorption dryer does not require an energy supply. This applies to the drying process, in which the dry air absorbs the moisture from the material to be dried, and also to the absorption process, in which the moisture is removed from the drying air. Not only does the absorption process require no energy, it also releases energy in the form of heat. This heat is used in the absorption dryer to speed up the drying process. The drying process would also work without this heat (with dry air that has not been specially heated.)

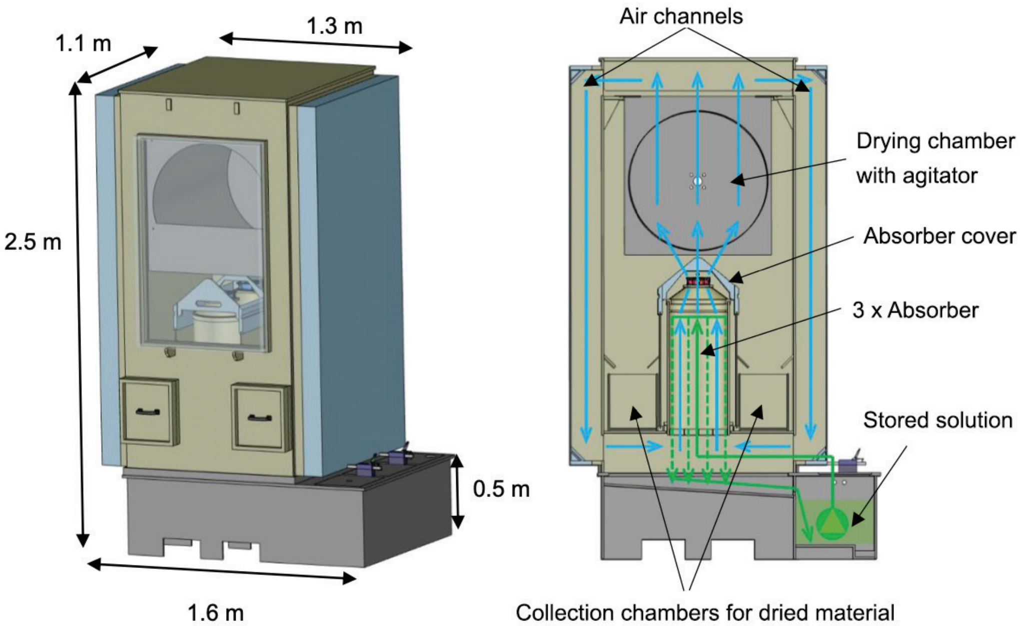
The sorptive drying system requires energy in two other steps: Firstly, for concentrating the liquid caustic soda solution in the desorber, for which low-temperature heat from solar thermal energy or industrial waste heat is very suitable. Secondly, electricity is needed to operate the pumps and fans as well as the heat pump of the desorber.



sidual moisture remained. This is ensured by an innovative agitator. Finally, the dryer had to be as compact as possible so that the fans for the drying air and the pumps for the absorber fluid required as little energy as possible

Regeneration in the desorber

A sorptive drying system does not only consist of the absorption dryer developed at the ZHAW. In addition, a desorber is required in which the absorption liquid is regenerated: Here, low-temperature heat is supplied to the diluted liquid caustic soda solution and concentrated in such a way that the liquid caustic soda can then be used again to dehumidify the drying air in the absorber. "The construction of a desorber can be implemented using known technical means and therefore does not pose any particular challenges," says Lukas Vontobel, who played a key role in the ZHAW project.



ZHAW functional model of the absorption dryer: In the upper part, the air (blue) flows through the herbs and dries them. Underneath are three absorbers that dehumidify and heat the air. During dehumidification, the liquid caustic soda (green) absorbs water vapor from the air. During this process, heat is released. Illustration: ZHAW

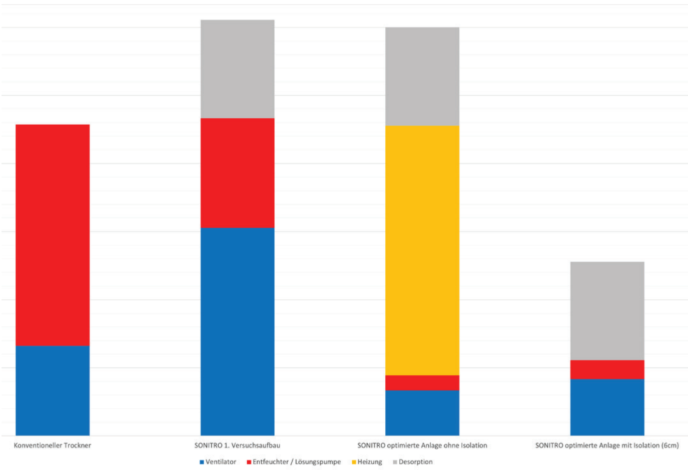
He and the research team investigated what a sorptive drying system would look like on an industrial scale. For the calculation, the scientists were guided by an existing drying system with heat pump dehumidifier, which is used by Holderhof Produkte AG in Niederwil (SG) for herb drying. There, herbs with a dry matter of 35 t are currently dried per year in a facility with a drying area of 800 m^2. A sorptive drying plant could dry the same amount of herbs on half the area (400 m^2) because of its higher throughput, the calculations have shown.

Regeneration throughout the year

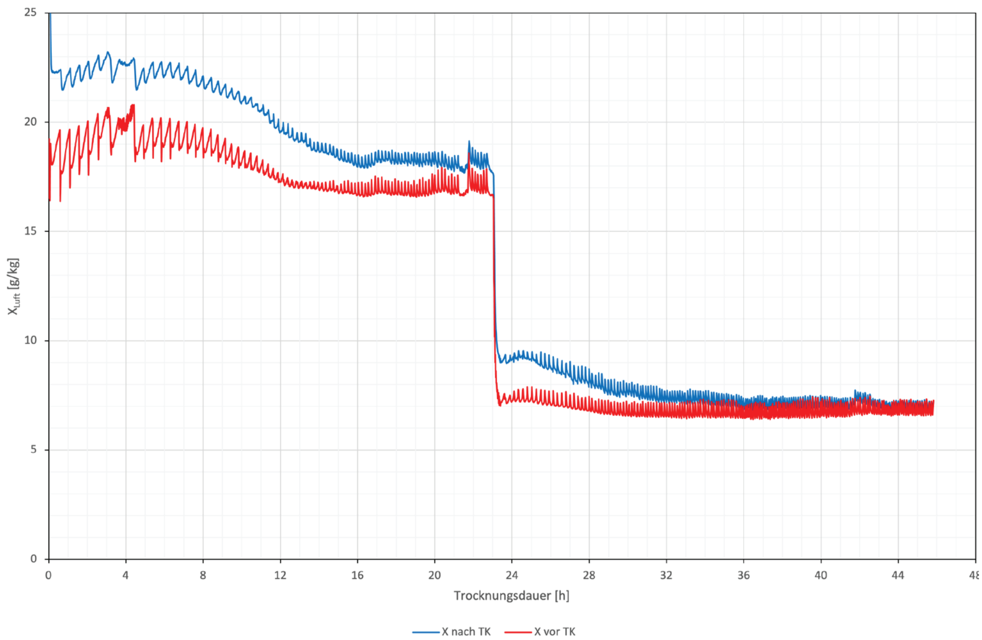
This drying capacity would require a double tank with a total capacity of 250 m^3. In one tank, the water-enriched (diluted) liquid caustic soda would be temporarily stored, in the other the regenerated (concentrated) liquid caustic soda. To regenerate the liquid caustic soda, a solar thermal system with an area of 250 m^2 would be required. "In our operating concept, we assume that the drying season lasts from May to October. The regeneration of liquid caustic soda would extend over the whole year," says ZHAW researcher Vontobel. Interestingly, around a fifth of the regeneration capacity would be provided during the winter months. Since regeneration would extend over the whole year, the solar thermal system could be built smaller and cheaper.

Industrial drying processes

Sorptive drying systems – as ZHAW research has shown – are technically feasible in principle. Initial estimates also show that they could also be economically competitive. In addition to herb drying, other industrial processes that are conceivable areas of application include: Paint shops, the food industry, or production facilities for building materials and ceramics. According to estimates, drying processes now account for 12 to 25% of the total energy demand, depending on the industry.



Energy consumption of the ZHAW dryer (second, third and fourth columns) compared to a conventional dryer (column on the left). The energy consumption for the fan (blue), pumps (red), heating of the absorption dryer (yellow) and regeneration of liquid caustic soda (grey) is shown. The second pillar shows the first version of the ZHAW functional model, the third pillar the current functional model, which is not yet insulated and therefore needs to be heated. In the future, insulation will make it possible to avoid the energy required for heating (column on the far right). If one does not take into account the energy required to regenerate liquid caustic soda, the ZHAW dryer (rightmost column) requires 75% less energy than the conventional dryer (leftmost column). Graphic: ZHAW



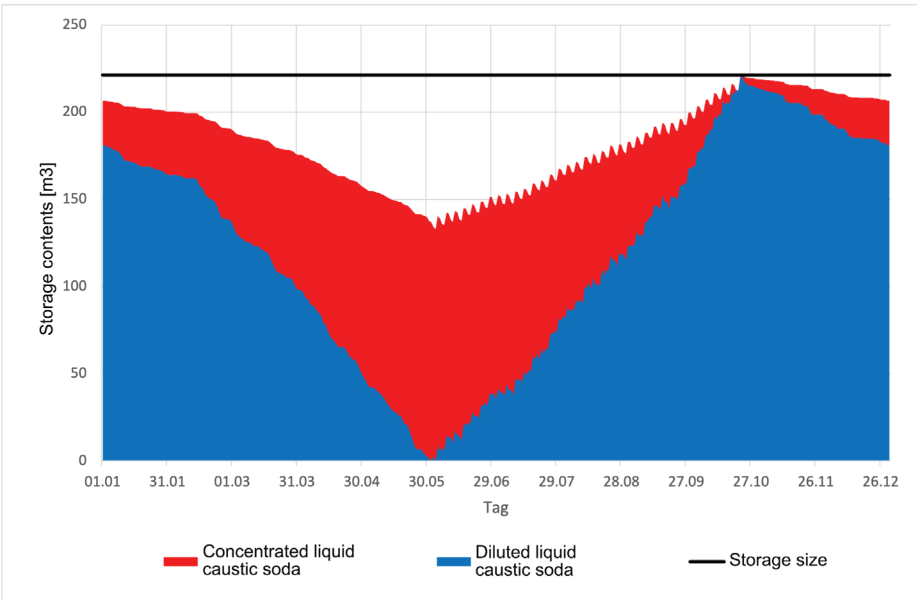
Water content of the air during the drying of peppermint plants at the entrance of the drying chamber (red) and at the exit (blue): The drying air absorbs water from the plants during the drying process. After about 40 hours, the plants have dried and the drying air no longer absorbs much water. During the first 23 hours, the caustic soda was diluted from 40% to 30% by the steam. Then the caustic soda solution was replaced by new, concentrated caustic soda (45%). As a result, the water load of the dry air decreases. The reason for this is that the higher the concentration of caustic soda, the lower the forced relative humidity at the absorber outlet. Graphic: ZHAW

Sorptive drying systems could reduce the use of fossil fuels and save electricity, according to the ZHAW›s final report.

- The **final report** of the project "SONITRO – Sorptive Low Temperature Drying" is available at: www.aramis.admin.ch/Grunddaten/?ProjectID=46572

- Further **articles** on research, pilot, demonstration and flagship projects in the field of industrial processes can be found under www.bfe.admin.ch/ec-prozesse.

The storage of an exemplary drying plant during the course of the year: In the first months of the year, no herbs are dried. The heat from a solar energy system is used to regenerate the caustic soda solution – the storage tanks now contain more and more concentrated caustic soda instead of diluted caustic soda. From June onwards, more caustic soda is used for the drying process than is simultaneously regenerated. As a result, the proportion of diluted caustic soda (saturated with steam) in the tanks increases. Graphic: ZHAW



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Version: April 2024