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Rapid concentration of high boiling point solvents using a vacuum-assisted vortex concentration method

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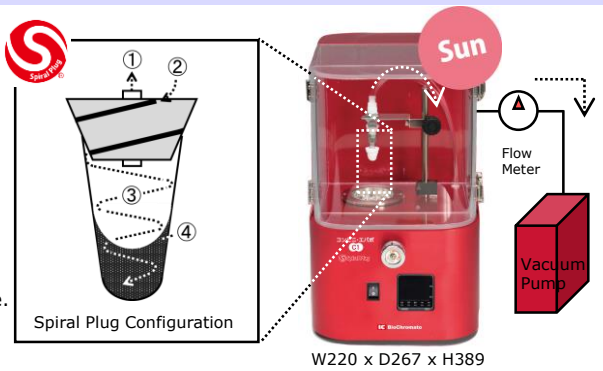
1. Introduction

In pharmacological research, concentrating solvents is an unavoidable operation. Herein, we propose a novel method of concentration; a Vacuum-Assisted Vortex Concentration method.
(hereinafter referred to as VVC method). A plug used in the VVS method has a hole in the center and helical grooves on the side surface. The plug is placed on the container mouth, (1) the air inside the container is exhausted with a vacuum pump, (2) Outside air flow is drawn into the container from the side grooves at high speed, (3) a helical spiral of air is generated, (4) the gas influx stirs the liquid surface thereby increasing the surface area of the liquid, which accelerates the evaporation speed.

The merits of the VVC method include the following points:

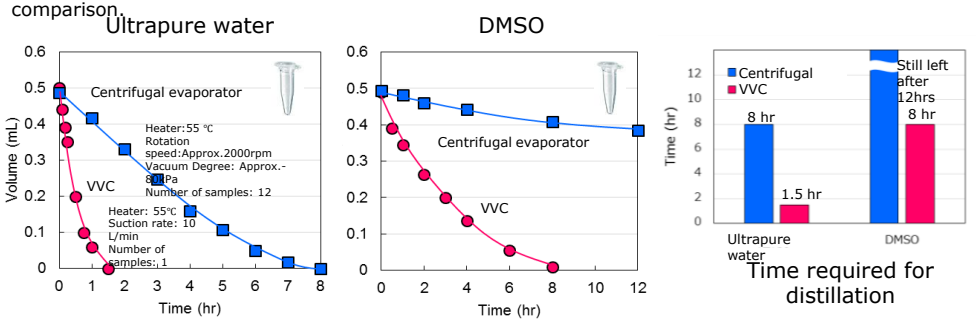
- Suitable for small volume exconcentration (~ several 10 mL).
- Can be concentrated in a short time when compared to existing methods.
- Bumping during concentration can be prevented since the solution is stirred under gentle reduced pressure.
- Any vial type can be used since there is no risk of implosion.



State of concentration
Left: Liquid surface is stirred
Right: Sample which easily foams can also be concentrated

2. Concentration speed comparison with existing method

In the VVC method, 0.5 mL of ultrapure water and Dimethyl sulfoxide (DMSO) were concentrated and the time required to concentrate was measured. A centrifugal evaporator was used for comparison.

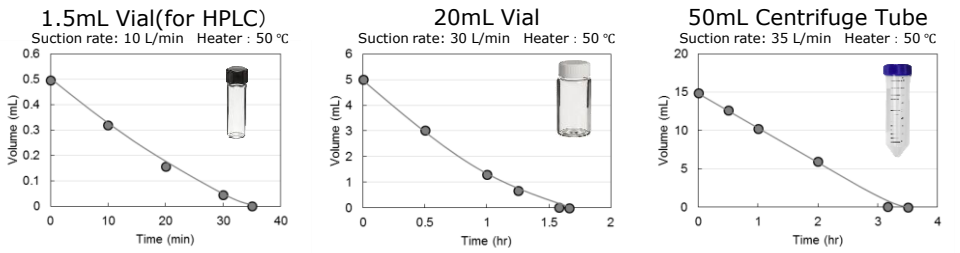


Time required for distillation

In the VVC method, it was shown that a higher boiling point solvent can be distilled (concentrated) faster than centrifugal evaporator, and the utility of this principle was confirmed.
In this experiment, a single vial concentrator was used. By using a multi-position model, it is possible to further increase the processing capacity.

3. Verification of compatible containers

Since the concentration is carried out under gentle reduced pressure in the VVC method, a container having a low pressure resistance can also be used for concentration. When a general storage container was used, the time required for drying down the solvent was verified.

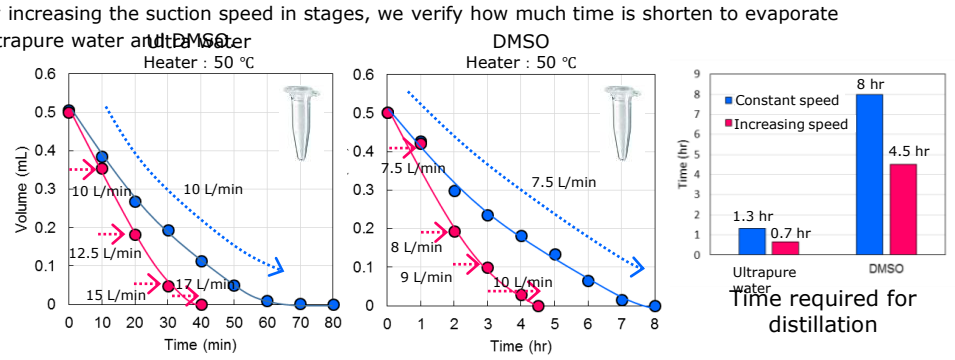


Other methods limit the types of compatible containers, while the VVC method concentration in any type of container. This eliminates the need to transfer into a different vial or flask for the evaporation step. By concentrating directly into the final storage container, there is no risk of sample loss, which maximizes yields.

4. Examination of concentration condition

▼4-1. Gas influx speed

As the solvent concentration develops, the sample surface level drops further from the Spiral Plug. As this "gap" between the solvent surface and Spiral Plug increases, the vacuum pumping speed should also increase in order to maintain stirring efficiency and optimal concentration rate. Therefore, by increasing the suction speed in stages, we verify how much time is shorten to evaporate ultrapure water and DMSO.

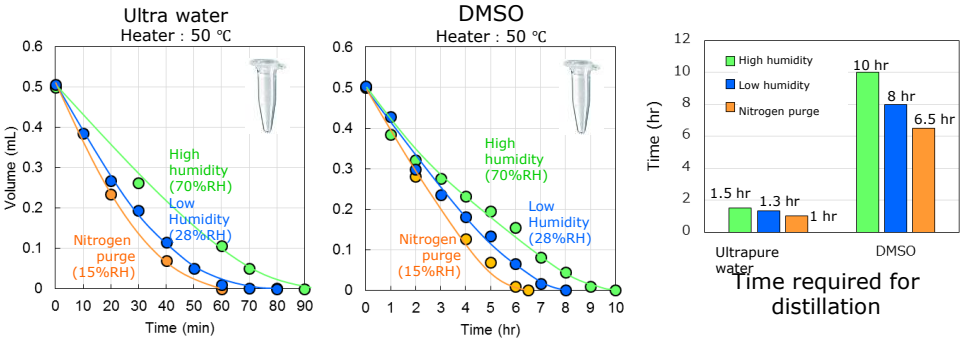


Time required for distillation

By increasing the vacuum pumping speed, the time taken to evaporate was reduced to about half. Therefore, increasing the pumping speed is an effective way to speed up the evaporation process.

▼4-2. Atmospheric humidity

Since the solution is stirred by atmospheric gas in the VVS method, evaporation efficiency is a concern under a high humidity atmosphere. The times required for evaporating ultra pure water and DMSO with different humidity conditions were measured, and the influence of humidity was evaluated.



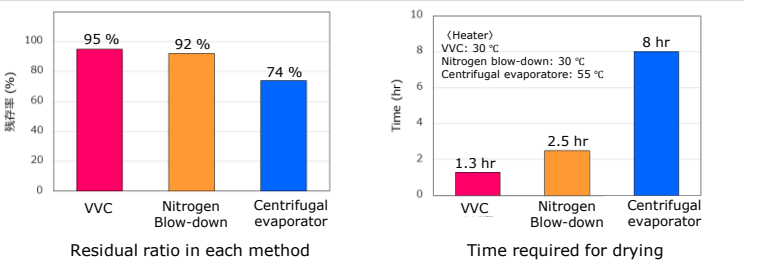
Time required for distillation

Evaporation is least efficient under high humidity conditions for both ultra pure water and DMSO. Alternatively, it is most efficient when the atmosphere is purged with nitrogen. By taking measures to reduce humidity, such as nitrogen purging, it is possible to obtain a higher concentration rate.

▼4-3. Temperature

Since the VVC method can concentrate in a shorter time than other methods, it is considered to be suitable for concentrating compounds that degrade when heat is applied. Therefore, 0.5 mL of a 1 mg / mL Vitamin C aqueous solution was used as a thermally unstable sample, and it was dried down by the following methods: The VVC method, a nitrogen blow-down system, and a centrifugal evaporator. The residual ratio was then compared by HPLC.

With the VVC method, it was confirmed that the residual ratio of Vitamin C is higher than other methods. With the VVC method, the sample can be concentrated and dried in a relatively short time, even at room temperature. Therefore, the VVC method is suitable for concentration of heat sensitive compounds and others.



Residual ratio in each method

Time required for drying

5. Conclusions

- The VVC method can quickly concentrate and evaporate off high boiling point solvents such as water and DMSO.
- Since a storage container can directly be used for evaporation, there is no risk of sample loss by sample transfer.
- Since the excessive decompression is not required, it can also be applied to samples that easily foam.
- By increasing the vacuum pumping speed as the sample volume decreases, concentration can be performed in a shorter time.
- By using dry nitrogen instead of air, solvent removal can be speeded up, that is also effective to prevent sample oxidation.
- Because it can be concentrated at room temperature, this method can also be applied to heat-sensitive compounds.

6. Future developments

- Flow meter ⇒ Develop a dedicated flow meter to maintain concentration and evaporation conditions
- Model that automatically varies vacuum pumping speed⇒ Develop a model that varies gas influx flow rate for improving concentration speed
- Combination with solid phase extraction ⇒ Develop a model that utilizes VVC technology to perform the solid phase extraction till to dry solidification.

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