

Oxygenation of Nutrient Reservoirs in Substrate-Based Soilless Crops

When growers new to hydroponics start working with soilless systems, one of the first questions that comes up is whether they should be actively aerating their nutrient solutions. Air stones bubbling away in reservoirs have become synonymous with hydroponics, particularly in deep water culture systems. However, when growing in substrates like coconut coir or rockwool, the situation is fundamentally different. Understanding where root oxygen comes from in substrate systems can help you avoid wasting resources on unnecessary equipment while also helping you understand the real limitations of these growing methods.

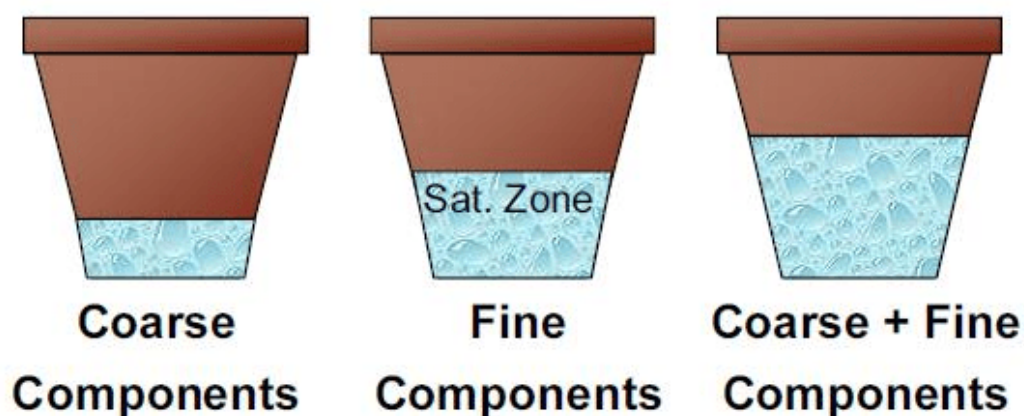


Figure 1. Influence of particle size on air and water distribution in growing substrates. Coarse particles create macropores that hold air after drainage, while fine particles create micropores that retain water. The balance between these determines oxygen availability to roots ([7](#)).

Where Roots Get Oxygen in Substrate Systems

In substrate-based growing systems, roots obtain nearly all their oxygen from air-filled pores within the growing medium,

not from dissolved oxygen in the nutrient solution. Substrates like rockwool and coconut coir typically have total porosities exceeding 80%, compared to typical soil porosities below 40% (1). This high porosity ensures there are enough water-filled pores for nutrient transport as well as enough air-filled pores for oxygen transport.

The key parameter governing oxygen availability in substrates is air-filled porosity, which represents the percentage of air contained in a fixed volume of substrate after it has been saturated with water and the free water has drained (2). Research on growing media has shown that adequate air-filled porosity levels for optimal plant growth typically range from 10-20%, with some studies suggesting that values above 20% may be necessary immediately after irrigation to prevent hypoxia (3).

When you irrigate a substrate, the nutrient solution displaces air in the open pores. As the substrate drains, air is drawn back down into the root system. This cycle of wetting and drying is what supplies roots with fresh oxygen. The oxygen diffusion coefficient in air is approximately 10,000 times higher than in water, which means that gas-phase oxygen transport through substrate pores is far more efficient than dissolved oxygen transport through water (4).

Substrate Type	Total Porosity (%)	Air-Filled Porosity at Field Capacity (%)	Water Holding Capacity (%)
Rockwool	95-97	15-20	75-80
Coconut Coir	85-90	20-30	60-70
Coco/Perlite (70:30)	85-90	25-35	55-65
Perlite	50-70	30-40	30-40

Does Nutrient Solution Oxygenation Make Sense?

The short answer is that in properly managed substrate systems with adequate irrigation frequency, oxygenating the nutrient solution in your reservoir provides minimal benefit to plant growth. The reason is simple: the overwhelming majority of oxygen uptake occurs through gas-phase diffusion in the air-filled pores of the substrate, not through dissolved oxygen in the water phase.

Research comparing water-based and substrate-based cultivation systems has demonstrated that substrate-grown plants can thrive even when oxygen supply through irrigation is potentially growth limiting, as long as the substrate maintains adequate air-filled porosity ([1](#)). In contrast, water culture systems where roots are continuously submerged rely entirely on dissolved oxygen, making aeration critical in those applications.

The irrigation strategy you use has far more impact on root zone oxygen than dissolved oxygen levels in your reservoir. Allowing substrates to dry down between irrigations increases air-filled porosity and draws fresh air into the root zone. Over-irrigation is far more likely to cause oxygen deficiency problems than low dissolved oxygen in your nutrient tank. When substrates remain saturated, air-filled pores fill with water, creating anaerobic conditions regardless of how much you aerate your reservoir.

The exception to this general rule would be in situations where you have continuous or very frequent irrigation with minimal drainage, essentially converting your substrate system into something closer to a water culture system. In such cases, dissolved oxygen becomes more important, but this represents poor management of a substrate system rather than a reason to add aeration.

The Pathogen Risk of Solution Aeration

While aerating nutrient solutions might seem harmless even if

unnecessary, there is a significant downside that growers should consider: the increased risk of introducing and spreading waterborne pathogens, particularly species of *Pythium* and *Phytophthora*.

These oomycete pathogens are among the most problematic diseases in hydroponic systems. They produce motile zoospores that can swim through nutrient solutions using flagella, allowing them to spread rapidly through recirculating systems (5). When closed hydroponic systems are used, pathogens can enter and then rapidly disseminate, particularly during periods of stress such as high temperatures or low dissolved oxygen levels (5).

Aeration systems create several opportunities for pathogen introduction and proliferation. Air stones and diffusers provide surfaces for biofilm formation where pathogens can colonize. The turbulence created by aeration helps distribute any pathogens present throughout the solution more effectively than they would spread by passive diffusion. The air being pumped into the system can carry airborne pathogen propagules, and unless you are using sterile filtration on your air intake, you are essentially inoculating your reservoir with whatever microorganisms happen to be in your growing environment.

Low dissolved oxygen has been reported to increase *Pythium* infection in hydroponic systems (6). However, in substrate systems where roots obtain oxygen primarily from air-filled porosity rather than dissolved oxygen, the relationship between solution aeration and disease suppression becomes less clear. The more relevant factors for disease prevention in substrate systems include maintaining proper irrigation frequency to ensure adequate substrate aeration, avoiding prolonged saturation, and keeping solution temperatures below 24°C where practical.

Pathogen Risk Factor	Risk Level with Aeration	Risk Level without Aeration
Airborne contamination introduction	High	Low
Pathogen distribution through solution	High (turbulent mixing)	Moderate (passive diffusion)
Biofilm formation sites	High (air stones, tubing)	Low (tank surfaces only)
Solution temperature increase	Possible (pump heat)	Minimal

Practical Recommendations

For growers using substrate-based systems, the evidence suggests that resources are better spent on proper irrigation management than on solution aeration. Focus on selecting substrates with adequate air-filled porosity, implementing irrigation schedules that allow periodic drying to refresh the air in the root zone, and maintaining appropriate solution temperatures.

If you are growing in pure water culture systems like deep water culture, NFT, or aeroponics, then maintaining adequate dissolved oxygen becomes critical and aeration or other oxygenation methods are necessary. But if you are growing in rockwool, coco coir, or similar substrates with good drainage, your plants are getting their oxygen from the air in the substrate pores, not from the water in your reservoir.

The key takeaway is this: in substrate systems, oxygen management happens at the substrate level through proper irrigation practices, not at the reservoir level through aeration. Understanding this fundamental difference can help you avoid unnecessary equipment costs while potentially reducing your risk of introducing waterborne pathogens into your growing system.

Coco Coir vs Rockwool in Soilless Crops

Choosing the right substrate is critical in greenhouse hydroponics. Coconut coir (coco peat) has become a renewable alternative to rockwool, and recent studies show it can match or exceed rockwool in many crops. In cucumbers, switching to coir improved leaf area and marketable yield [\(1\)](#). In tomatoes, coir supported higher fruit yield and nutrient uptake than rockwool [\(2\)](#). In leafy greens, lettuce in coco peat produced more biomass than mineral wool or perlite in controlled greenhouse trials [\(3\)](#). Even strawberries have shown equal or better performance in coir compared to rockwool when root-zone aeration is properly managed [\(4\)](#).



A 70:30 coco/perlite blend, one of the best blends to use in soilless cultivation, especially for plants with high oxygen demand

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- **Tomato:** Coir gave higher yields and heavier fruits than rockwool. Plants on coir had significantly greater uptake of potassium and sulfur, translating to larger fruit and more total yield [\(2\)](#).
 - **Cucumber:** Coir boosted growth and yield compared to rockwool. Leaf area index and final yield were consistently higher on coir [\(1\)](#).
 - **Lettuce:** Coco peat produced ~40% higher leaf biomass than perlite and ~70% higher than mineral wool in one ebb-and-flow greenhouse study [\(3\)](#). In another greenhouse system, rockwool gave the heaviest fresh biomass, but coir produced taller plants and longer roots [\(5\)](#).
 - **Strawberries:** Over six months of pot cultivation, strawberries grown in coir matched or outperformed rockwool in shoot dry weight, while showing more stable drainage EC and pH [\(4\)](#). Extension reports and grower trials further suggest blends of coir with perlite improve aeration and flowering compared to pure coir [\(6\)](#).
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Crop Comparison Table

Crop	Rockwool Yield	Coco Coir Yield	Notes/Ref
Tomato	Lower	Higher (2)	Heavier fruit, greater K and S uptake
Cucumber	Lower	Higher (1)	Higher LAI, yield, nutrient levels

Crop	Rockwool Yield	Coco Coir Yield	Notes/Ref
Lettuce	Moderate	Higher (3) (5)	Coco peat surpassed mineral wool in one study; rockwool still led in fresh biomass in another
Strawberry	Variable	Equal or higher (4) (6)	Coir stable for EC/pH; blends improve aeration

Tomatoes on Coir vs Rockwool

In the tomato trial by Xiong et al., coir substrates significantly outperformed rockwool. Plants in coir had higher total fruit yield, greater average fruit weight, and better uptake of key nutrients such as K and S [\(2\)](#). This demonstrates that coir is not just a substitute but a potentially superior medium for greenhouse tomato production.

Cucumbers on Coir vs Rockwool

In greenhouse cucumbers, coir consistently gave higher vegetative vigor and fruit yield. Leaf area index and final yields were significantly higher than on rockwool [\(1\)](#). Nutrient analysis also showed higher Ca, Mg, and Zn contents in coir-grown plants, suggesting coir buffers nutrients more effectively.

Lettuce and Leafy Greens

In Polish greenhouse trials, coco peat lettuce heads produced substantially more leaf biomass than those grown in mineral wool or perlite (3). In contrast, a Philippine hydroponic study found rockwool produced the heaviest fresh biomass, but coco coir gave taller plants and longer roots (5). Together, these results show coir can rival or surpass rockwool, but outcomes depend on system design and cultivar.

Strawberries on Coir vs Rockwool

In Korea, a six-month hydroponic strawberry trial showed that coir matched or outperformed rockwool in shoot dry weight, while maintaining more stable EC and pH in drainage solutions (4). Practical experience also suggests that coir blended with perlite is best for strawberries, as it improves root aeration and prevents waterlogging (6). For crops that have roots that require high oxygenation, perlite amendments are fundamental to the use of coco coir for optimum results.

Coco/Perlite Blends

Many growers prefer mixing coir with perlite to improve aeration. This is especially useful for crops like strawberry, which are sensitive to low oxygen in the root zone. A 70:30 coir:perlite ratio is widely used to combine coir's nutrient buffering with perlite's porosity. **These blends often outperform pure rockwool in practice.**

Summary

Greenhouse research consistently shows that **coir is a strong alternative to rockwool**. Tomatoes and cucumbers perform better on coir, lettuce often produces more biomass, and strawberries grow well provided aeration is managed. Coco/perlite blends add further reliability. For growers aiming to reduce reliance on rockwool, coir and its blends represent a proven, effective option that can sustain or increase yields while offering better root-zone stability.