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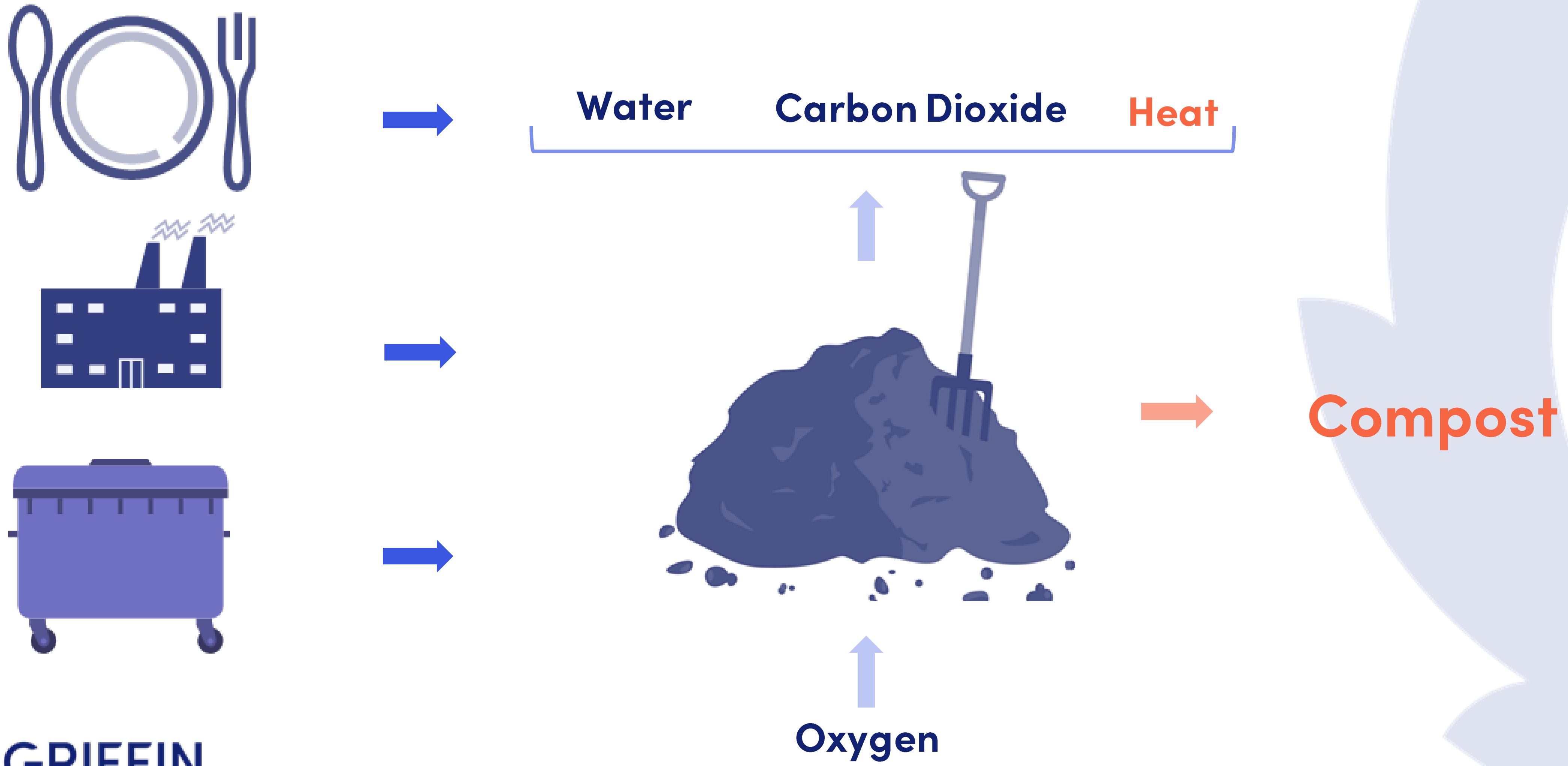
# Composting of Sludge and Organic Waste

WAT-E2180 - Biological Treatment of Water and Waste

Waste reimagined

# The Composting Process

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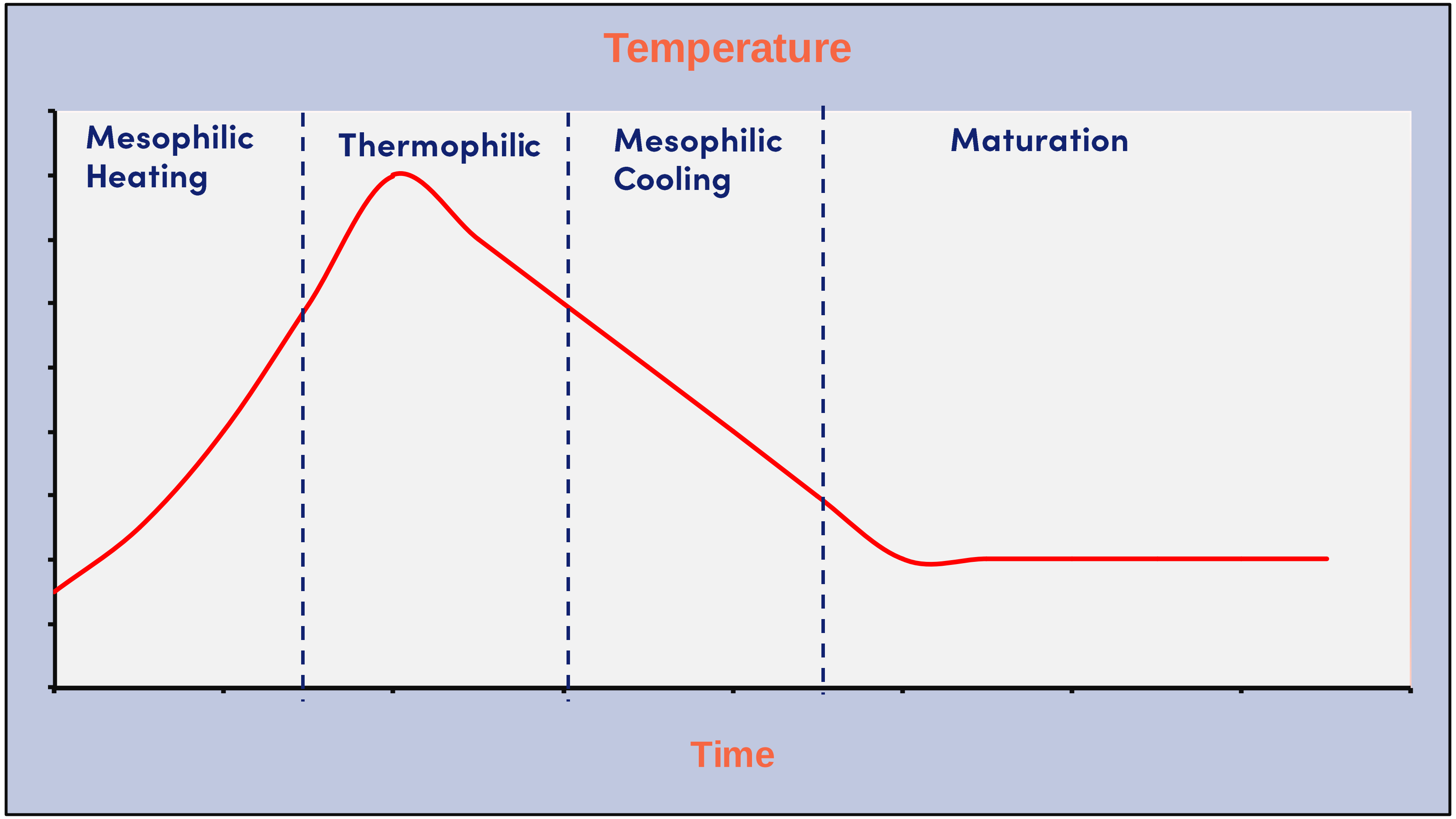
# The Composting Process




- Temperature variation is a result of microbial activity. Endogenous process
- Optimum temperature for microbes is between 35 and 55 °C.
- High temperature kills pathogens (70 °C)

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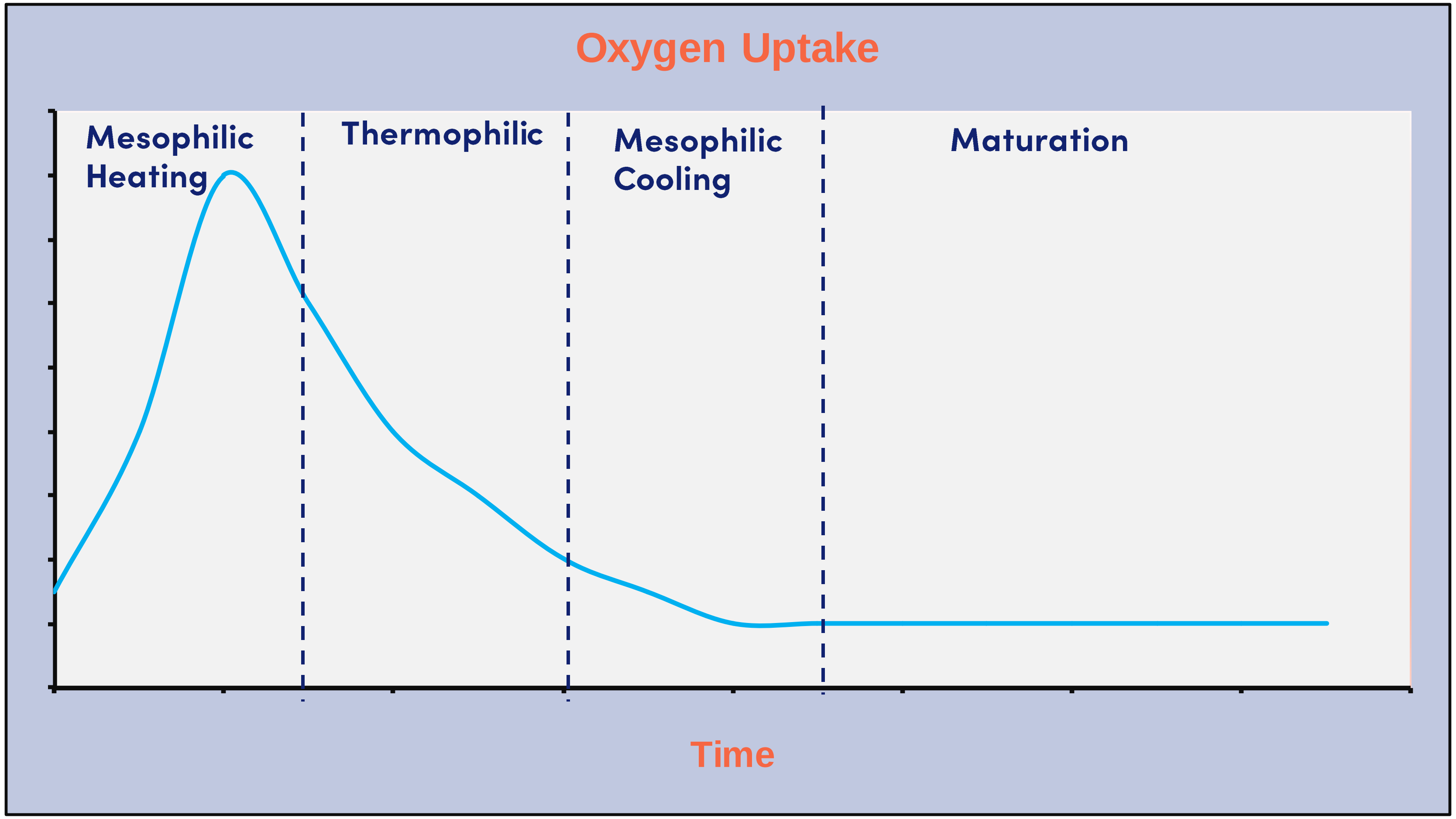


- Microbes metabolism require oxygen to grow and degrade organic matter.
- Oxygen is continuously consumed
- Oxygen content inside the mass cannot fall much below normal air oxygen level

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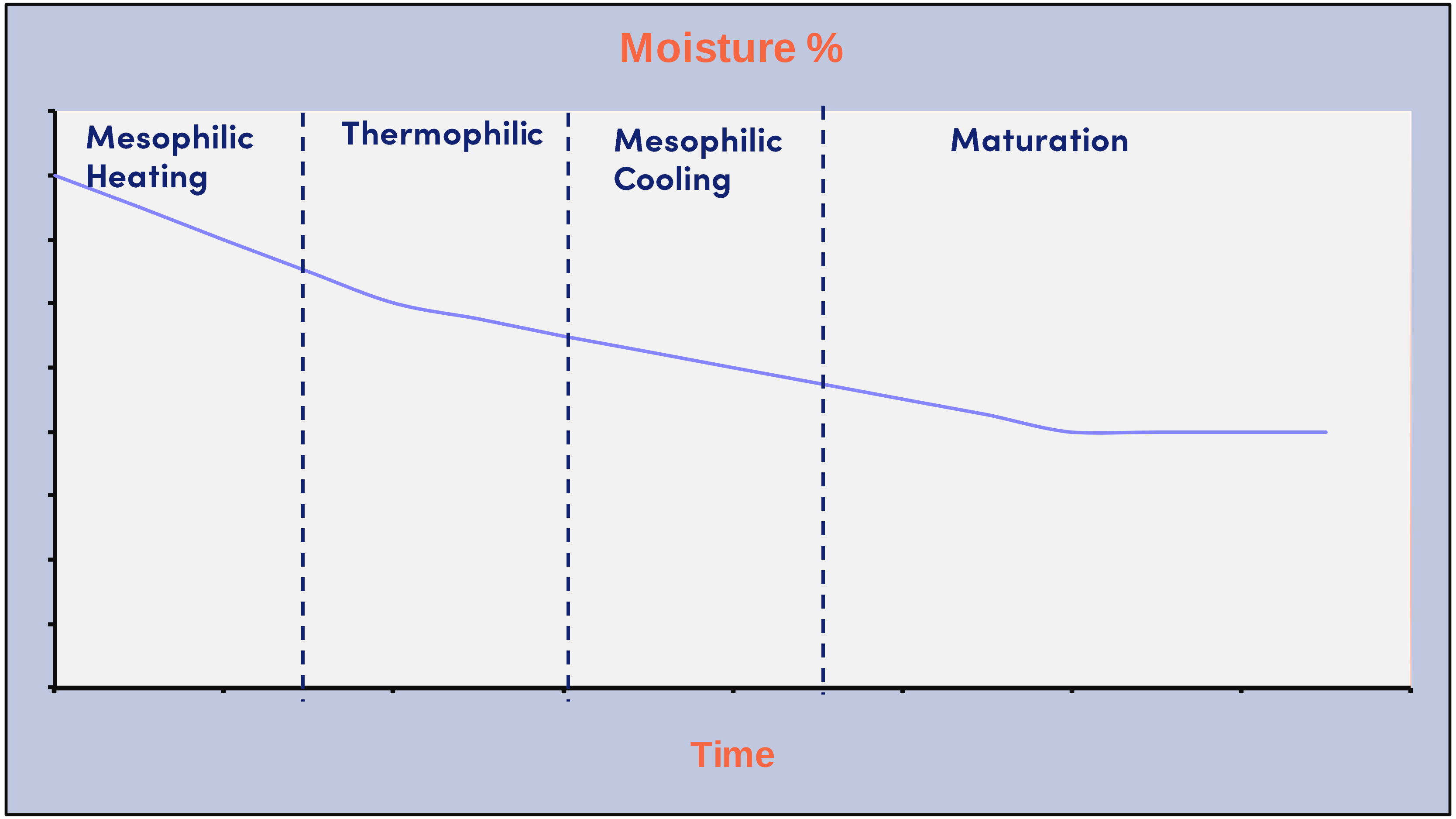


- Initial moisture not below 60%
- Decreases steadily throughout the process
- Never below 50-40%

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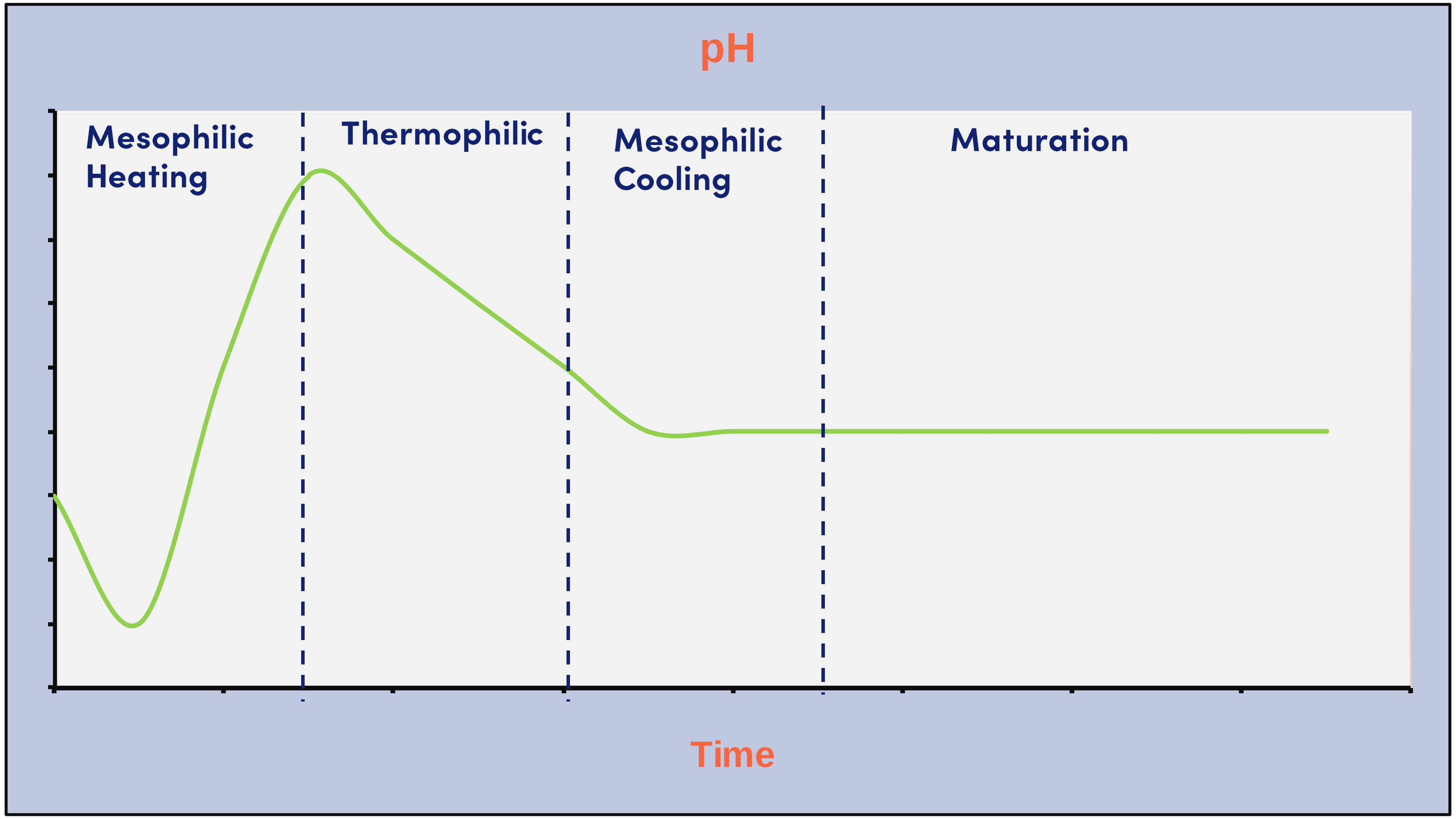


- Optimum pH range for compostable material is between 5.5 and 8.0.
- pH variation is the result of microbial activity
- At the end of the process pH is between 7.5-8

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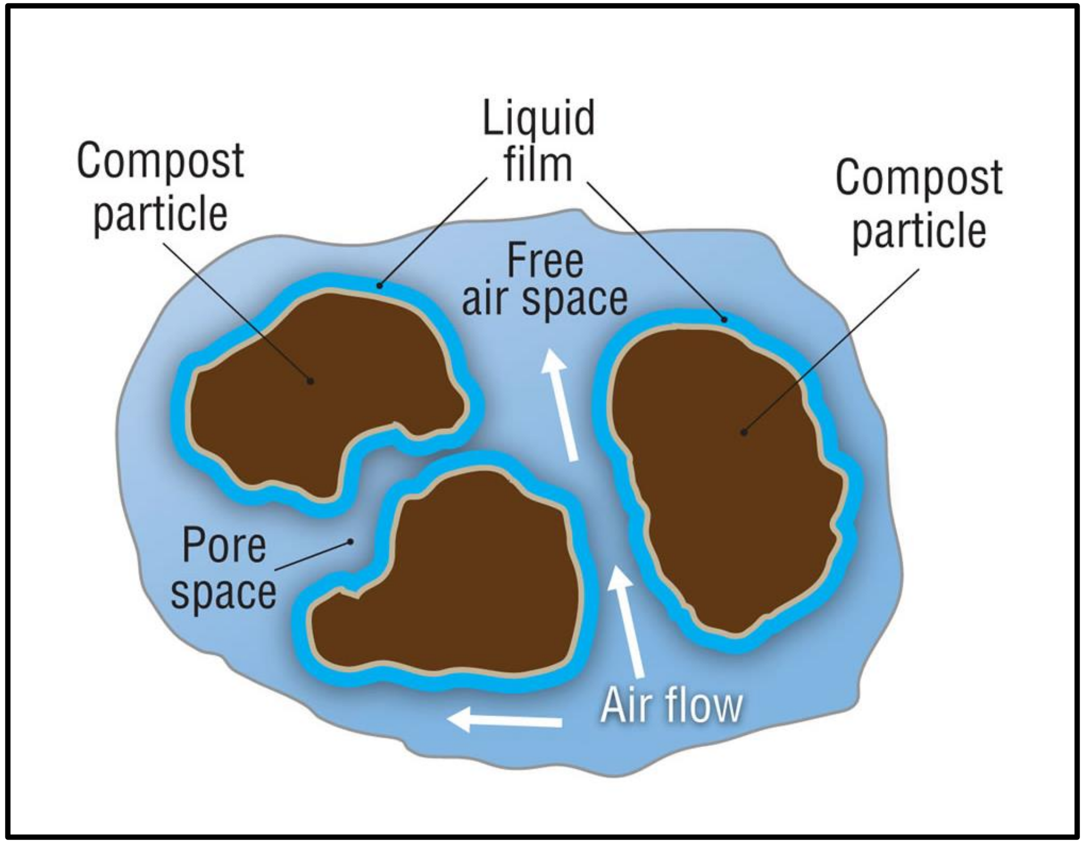
# The Feedstock Characteristics

## Physical characteristics




- The correct moisture (70-60 %) is essential for the microbial activity

- The proper density(600 – 700 kg/m$^3$) enables sufficient air flow through the organic mass

- The right particle size guarantees enough surface area/volume for efficient microbial activity

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# The Feedstock Characteristics

## Chemical characteristics

- Macro and micronutrients availability
- Optimal C/N ratio is between 25:1-30:1
- High C/N ratio diminishes biological activity
- Low C/N ratio leads to ammonia volatilization during the process which which can cause the release of bad odours

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# The Composting Process Objectives

| | | |
|---|---|---|
| **Stabilization** | → | **Complete degradation of organic matter (14 to 180 days)** |
| **Hygienization** | → | **According to EU directive 1 hour at 70 °C or 7 days at 60 °C** |
| **Viable Product** | → | **Organic fertilizer or soil amendment** |

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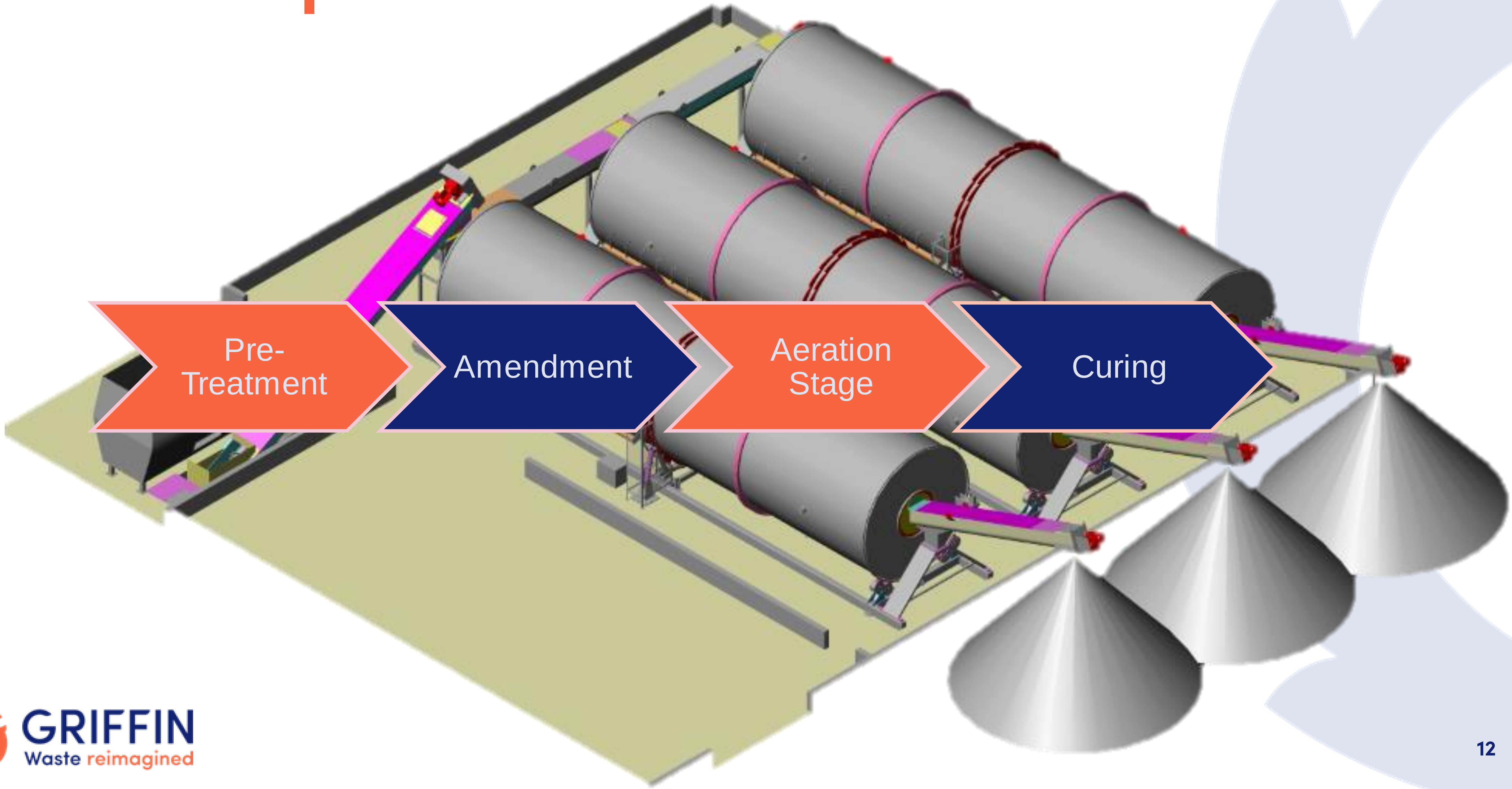
# How do we design a modern composting plant?

# The Feedstock Characteristics

| Substrate | C:N ratio | Moisture % |
|---|---|---|
| Liquid Manure | 2-3 | 98 |
| WWTP Sludge 20% TS | 5 | 80 |
| Animal Manure | 10-25 | 85-95 |
| Food waste | 13-23 | 70 |
| Fruit | 35 | 65 |
| Garden Waste | 40-60 | 55 |
| Straw | 60-70 | 20 |
| Sawdust | 100-500 | 30-60 |
| Cardboard | 200-500 | 10 |
| Wood Chips | 250-350 | 30 |

# The Set-Up



# The Pre-Treatment

- Removal of impurities (plastic, metals, etc.)
- Size reduction
- Blending of different feedstocks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# The Amendment

- Addition of support material
- C:N ratio adjustment
- Moisture adjustment
- Homogeneous mixing
- Proper density

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# The Aeration Stage

**This is the core that allows achieving the primary targets of the whole aerobic process**

**How much air?** → Aeration Requirement

Aeration Requirement →
- Organic matter decomposition
- Water removal
- Heat Removal

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# The Curing

- Cooling
- Refining of the end product
- Removal of small impurities



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# Aeration for organic matter decomposition

## Stoichiometric oxygen demand

$C_{10}H_{19}O_3N + 12.5O_2 \longrightarrow 10CO_2 + 8H_2O + NH_3$

x = 12.5(32)/201 = 1.99 g $O_2$/g BVS substrate

1.99/0.23 = 8.65 g air/ g BVS substrate

8.65/1.2 = 7.2 l air/ g BVS substrate

## Assumptions

- Negligible nitrification
- Complete biodegradation
- BVS fraction percentage
- Full aerobic conditions

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# Aeration for Water Removal

**Water to evaporate**

$W = [ (1-S_S) / S_S ] - [ (1-V_S) / (1-V_P) ] [ (1-S_P) / S_P ]$

**Water content in air**

$\log_{10} PVS = a / T_a + b$

$PV = RHAIR (PVS)$

$w = (18 / 29) [ PV / (PAIR – PV)]$

**Air requirement**

$A = W / w$

**Assumptions**

- Support material not accounted
- Conservative ash content
- Fixed pressure and temperature
- Full aerobic conditions

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# Aeration for Heat Removal

**Heat estimation**

Straight from stoichiometric oxygen demand

$H_g$ = (g $O_2$/g BVS substrate) (cal/g $O_2$)

**Air requirement at To**

$H_{Ti} = A\, w_{Ti}\, K_{Ti}$

$H_{wtot} = A\, (w_{tot})\, K_w\, (To - Ti)$

$H_{To} = A\, K_w\, (To - Ti)$

**Air for heat removal**

$A = H_g / [\, w_{Ti} K + (w_{tot})\, K_w\, (To - Ti) + K_w\, (To - Ti)]$

**Assumptions**

- Steady state conditions
- Absence of heat loss

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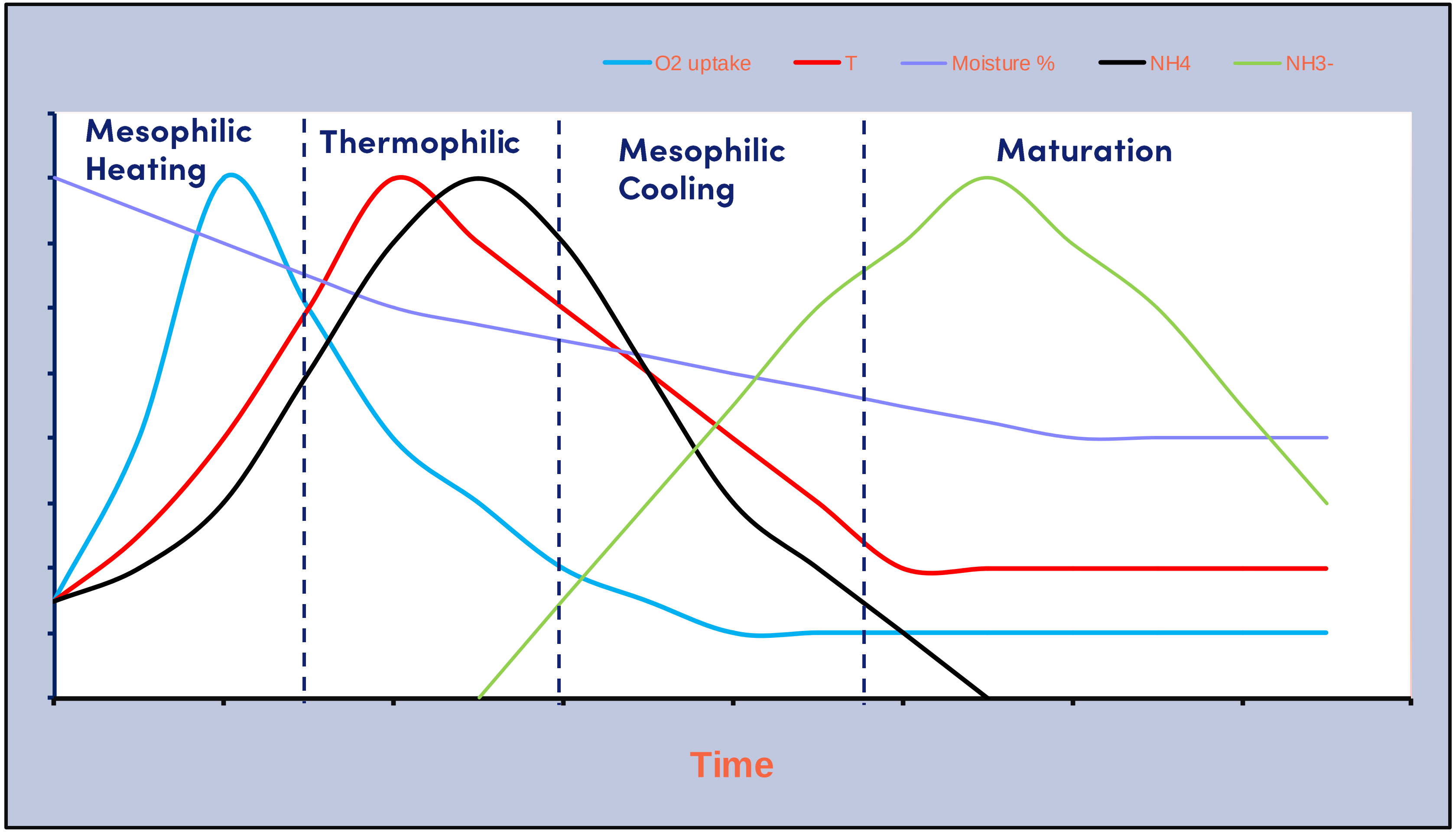
# Aeration Benefit and Challenges




- Aeration rates
- Reactions balancing
- Ammonia volatilization
- Control strategies
- We do not see air!

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# Windrow/Forced aeration pile Composting

- Batch process
- Mechanical or forced aeration
- Simple air flow control
- Direct temperature control

- Simple operation
- Low investment
- Contamination risk
- Low end product quality

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# Tunnel Composting

- Batch process
- Mechanical or bottom aeration
- Air flow control
- Direct temperature control

- Intensive operation
- Large investment
- Long residence time
- Poor or absent mixing

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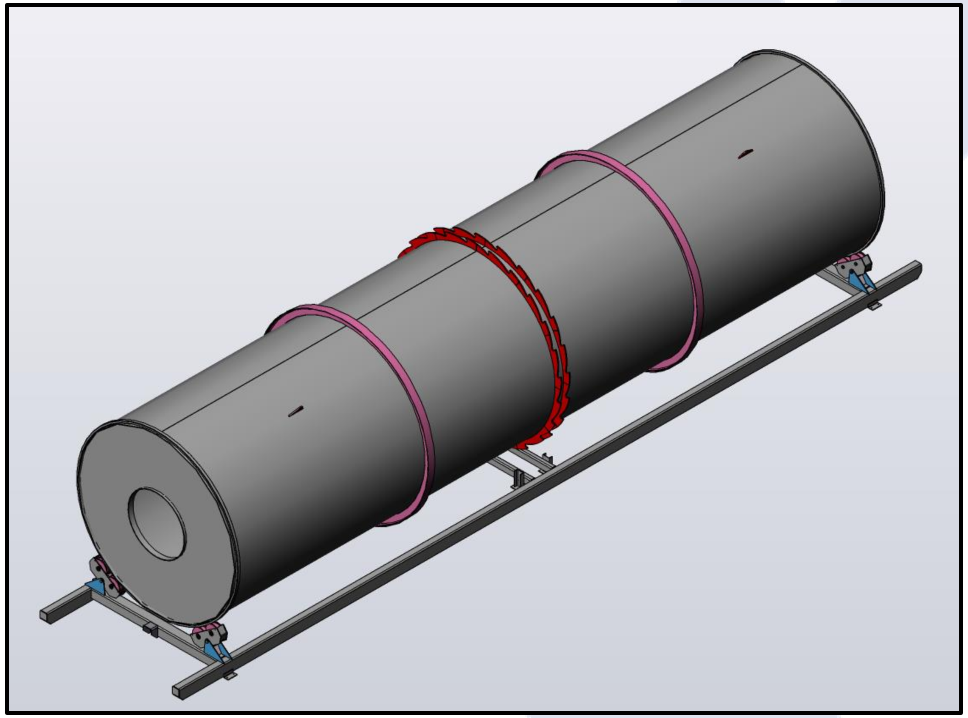
# In-vessel Composting

- Continuous process
- Grid aeration
- Total air flow control
- Feedback temperature control
- Feedback moisture control



- Demanding operation
- High investment
- Short residence time
- High end product quality

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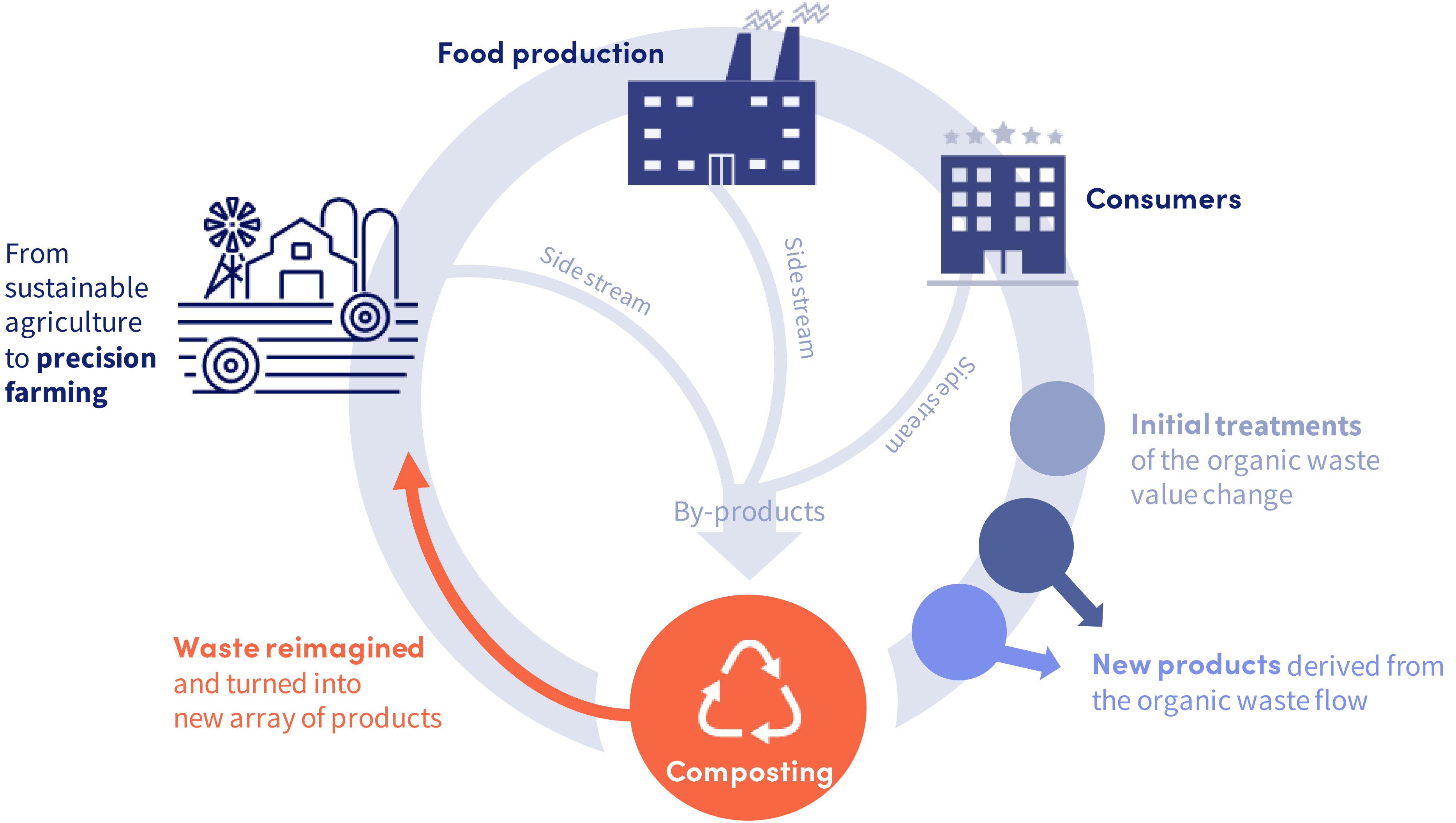
# Organic matter flow in bioeconomy



# End-product's features

**MACRO NUTRIENTS AVAILABILITY**

- Nutrients available in the proper form for crops
- Slow and natural release in the soil

**WATER RETENTION CAPACITY**

- Improved retention of water
- Better growth of crop in the long term

**CARBON SEQUESTRATION**

- Efficient route to balance the carbon cycle
- Indirect impact on $CO_2$ emissions

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# Compost & Biochar

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# Precision Farming

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# Organic Fertilizers

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# Thank you!

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