# Fermentation Does Not Reach a Hundred Percent Because the Catalyst Has to Build Itself, Not Because the Work Is Poor

— the theoretical yield of ethanol fermentation stops at **0.511423** g/g, and because the catalyst, the yeast, must build itself, giving **5** % of the sugar to biomass lowers **12.963839** %vol to **12.315647** %vol — the separator is whether the catalyst self-replicates — [Paper 716]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
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— *From thinking to syncing.* —

**Abstract**

**Sugar does not all become alcohol, and not because the work is clumsy. There are two reasons, and both lie on the side of principle.Where the ceiling sits is counted from the mass balance.No new theorem or law is claimed. First, the reaction equation sets a ceiling——the theoretical yield is 0.511423 g/g and 0.488565 of the mass necessarily leaves as carbon dioxide** (Section 2). **Second, the balance closes——the two sum to 0.999989, the shortfall of $1.110 \times 10^{-5}$ being the rounding of 180.156 against the products' 180.154** (Section 2). **Third, in terms of sugar concentration the ceiling becomes visible——from 200 g/L the theoretical maximum is 102.284687 g/L, or 12.963839 %vol** (Section 2). **Fourth, and this is the core. The second ceiling lies with the catalyst——the yeast must build itself, and giving 5 % of the sugar to biomass brings the figure to 12.315647 %vol** (Section 3). **Fifth, a chemical catalyst carries no such loss——needing no construction of itself, it does not eat the feedstock** (Section 3). **Sixth, the separator is whether the catalyst self-replicates——before calling a yield poor, one must say which ceiling is in view** (Section 4). **Keywords**: alcoholic fermentation, theoretical yield, mass balance, biomass formation, self-replicating catalyst, two ceilings.

**Scope of this paper (scope note)**: **No new theorem or law is claimed——both the stoichiometry of alcoholic fermentation and the yield loss to biomass formation are standard (Gay-Lussac 1815, Bailey and Ollis 1986).No yield of a real yeast or process is claimed——the 5 % given to biomass is a representative value assumed here.By-products are not treated——branching to glycerol and organic acids is not counted.Conditions are not discussed——temperature, pH, nutrients and product inhibition are not treated.Downstream processing is not treated——distillation and concentration are not entered; the strengths shown are those of the fermented liquid.Relation to earlier papers**: **Paper 680 showed that what is frightening about exponential growth is not its speed but that half of it sits in the last doubling——there a yield was given and the allocation of time was counted. Here the ceiling on that yield itself is counted: one step down, onto the side of the assumption.**What is added is **deriving the theoretical yield of $\mathbf{0.511423}$**, **showing the balance to close against the $\mathbf{0.488565}$ leaving as carbon dioxide**, **putting the ceiling from 200 g/L at $\mathbf{12.963839}$ %vol**, **quantifying the catalyst's own construction at $\mathbf{12.315647}$ %vol**, and **placing the separator on whether the catalyst self-replicates**.

## 1. Notation and the Question

**Setting**: **alcoholic fermentation turns one molecule of glucose into two of ethanol and two of carbon dioxide. By mass, part of the feedstock necessarily departs as gas.**

$$\mathrm{C_6H_{12}O_6} \rightarrow 2\,\mathrm{C_2H_5OH} + 2\,\mathrm{CO_2}, \qquad Y = \frac{2M_{\text{ethanol}}}{M_{\text{glucose}}}$$

**Furthermore the catalyst driving this reaction is a living cell, and the cell itself is built from the sugar.**

**Question**: **where is the ceiling on yield, and how many ceilings are there?**

## 2. The First Ceiling Is in the Equation

**Computation 2.1**: **the mass balance was derived.**

| destination | fraction of the feedstock mass |
|---|---|
| ethanol | $\mathbf{0.511423}$ |
| carbon dioxide | $\mathbf{0.488565}$ |
| sum | $\mathbf{0.999989}$ |

> **Observation 2.2**
>
> **the balance closes.The sum is $0.999989$, short of $1$ by only $1.110 \times 10^{-5}$, and that shortfall is the rounding of the tabulated values $180.156$ against the products' $180.154$——no mass is unaccounted for: that nearly half the sugar does not become alcohol is not leakage but the appointed departure of carbon dioxide.**

**Computation 2.3**: **the amount obtainable from $200$ g/L of sugar was derived.**

| actual yield against theory | ethanol | strength |
|---|---|---|
| **100** % | **102.284687** g/L | **12.963839** %vol |
| **95** % | **97.170452** g/L | **12.315647** %vol |
| **90** % | **92.056218** g/L | **11.667455** %vol |

> **Observation 2.4**
>
> **the sugar concentration sets the ceiling on strength.At $200$ g/L nothing above $12.963839$ %vol is reachable——however carefully the batch is prepared, no more comes out than the sugar put in.**

## 3. The Second Ceiling Lies with the Catalyst

> **Observation 3.1**
>
> **this is the core: the yeast must build itself.The carbon for new cells also comes from the sugar, so some of it necessarily does not go to ethanol——giving $5$ % of the sugar to biomass takes the strength from $12.963839$ to $12.315647$ %vol.**

> **Observation 3.2**
>
> **this loss cannot be worked away.Without a catalyst the reaction does not proceed, and building a catalyst takes feedstock——unlike the ceiling in the equation, this one comes from the nature of the catalyst.**

**Observation 3.3**

**a chemical catalyst carries no such loss.Platinum does not build itself and works on without eating the feedstock——the difference between a biological and a chemical catalyst shows up in a single number, the yield.**

**Observation 3.4**

**so “the yield is poor” reads two ways.Either the equation’s ceiling is near, or the biomass is taking it——in the first case there is no room to improve; in the second there is room in the pitching rate and the growth conditions.**

**Observation 3.5**

**the two ceilings pull opposite ways.Less biomass leaves more sugar for ethanol, but less catalyst makes the reaction slower——yield and speed compete for the same allocation.**

## 4. The Separator

**Observation 4.1**

**the separator is whether the catalyst self-replicates.A self-replicating catalyst eats the feedstock; one that does not, does not——two different ceilings live under the single word “yield”.**

**Observation 4.2**

**beside Paper 680.Paper 680 showed that what is frightening about exponential growth is not its speed but that half of it sits in the last doubling——there a yield was taken as given and the allocation of time was counted. Here the ceiling on that given number is counted: one step down onto the assumption.**

**Observation 4.3**

**what is not said.Real yeasts, by-products, conditions and distillation are not treated, and the 5 % to biomass is assumed——what is shown is that there are two ceilings and that one of them comes from the nature of the catalyst.**

## 5. Roll Call and Closing

1. **theoretical yield 0.511423** (Computation 2.1): **set by the equation.**
2. **carbon dioxide 0.488565** (Computation 2.1): **it must depart.**
3. **sum 0.999989** (Computation 2.1): **the balance closes.**
4. **102.284687 g/L** (Computation 2.3): **from 200 g/L of sugar.**
5. **12.963839 %vol** (Computation 2.3): **the ceiling.**
6. **5 % to biomass: 12.315647 %vol** (Observation 3.1): **the core.**
7. **at 90 % of theory, 11.667455 %vol** (Computation 2.3): **for comparison.**
8. **a chemical catalyst does not eat** (Observation 3.3): **it builds no copy of itself.**
9. **yield competes with speed** (Observation 3.5): **one allocation of sugar.**
10. **does it self-replicate** (Observation 4.1): **the separator; Paper 680.**

**Closing**: **Fermentation does not reach a hundred percent because the catalyst has to build itself, not because the work is poor.There are two ceilings.The first is in the equation: since glucose at $180.156$ yields $2 \times 46.068$ of ethanol, the theoretical yield stops at $0.511423$ g/g and $0.488565$ of the mass necessarily leaves as carbon dioxide, the two summing to $0.999989$, the shortfall of $1.110 \times 10^{-5}$ being the rounding of the tabulated values and not lost mass.From 200 g/L of sugar the maximum is $102.284687$ g/L, or $12.963839$ %vol, and no care in preparation brings out more than the sugar put in.The second ceiling lies with the catalyst——the yeast must build itself from the same sugar, so giving 5 % to biomass brings the strength to $12.315647$ %vol.This loss cannot be worked away——without a catalyst nothing proceeds, and building one takes feedstock.Platinum builds no copy of itself and carries no such loss, so the difference between a biological and a chemical catalyst appears in a single number.And the two ceilings pull opposite ways: less biomass raises the yield and slows the reaction.The separator is whether the catalyst self-replicates.Placed among the earlier papers——Paper 680 gave a yield and counted the allocation of time; here the ceiling on that given number is counted.To be honest——real yeasts, by-products and distillation are not treated, and the 5 % to biomass is assumed.**

## References


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**Yuuki YAMAGISHI (山岸 勇輝)**



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