

MediumFBA – A MATLAB Application for Integrated Medium Design and Flux Balance Analysis

The screenshot displays the MediumFBA MATLAB application interface, which is divided into seven main panels for integrated medium design and flux balance analysis.

Panel 1 - Select Strains: Shows a list of selected strains with their model names, numbers, genes, and metabolites.

Strain Model	Number	Genes	Metabolites
Clostridium_difficile_CD196	1	899	1170
Enterobacter_cloacae_EcWSU1	2	1325	1414
Escherichia_coli_str_K_12_substr_MG1655	3	1190	1348
Klebsiella_pneumoniae_pneumoniae_MGH78578	4	1393	1379

Panel 2 - Define Core Medium: Shows the core medium list and nutrient list.

Core Nutrient	Uptake Bound	Strains Transporter
Ammonium	-1000	1 2 3 4
Chloride	-1000	1 2 3 4
Co2+	-1000	1 2 3 4
Cu2+	-1000	1 2 3 4
Fe2+	-1000	1 2 3 4
Fe3+	-1000	1 2 3 4
Mn2+	-1000	1 2 3 4
Sodium	-1000	1 2 3 4

Panel 3 - Define Medium Design Constraints: Shows constrained and excluded nutrient lists.

Included Nutrient	Uptake Bound	Strains Transporter
Ammonium	-1000	1 2 3 4
Chloride	-1000	1 2 3 4
Co2+	-1000	1 2 3 4
Cu2+	-1000	1 2 3 4
D-glucose	-5	1 2 3 4

Excluded Nutrient	Uptake Bound	Strains Transporter
O2	0	1 2 3 4

Panel 4 - Design Growth Medium: Shows LP Solver settings and design strains.

Growth Nutrient	Strain 1	Strain 2	Strain 3	Strain 4
proton	12.4190	-992.5885	-31.6608	13.4887
sulfate	-0.4521	-0.1829	-90.0652	-0.0811
L-leucine	-1000	-0.3734	-5.4497	-0.1319
(R)-Pantothenate	-0.0329	-0.0050	-0.1940	-0.0047
Pyridoxine	-0.0165	-0.0025	-0.0970	-0.0023
L-tryptophan	-0.1130	-997.9106	-1000	-0.0166
L-valine	-15.2275	-0.2856	-5.1135	-0.1238

Panel 5 - Refine Growth Medium: Shows refined nutrient list.

Refined Nutrient	Uptake Bound	Strains Transporter
L-leucine	-1	1 2 3 4
L-tryptophan	-1	1 2 3 4
L-valine	-1	1 2 3 4
Mn2+	-1000	1 2 3 4
Pyridoxine	-1000	1 2 3 4
Sodium	1000	1 2 3 4

Panel 6 - Simulate Refined Medium: Shows simulation results for four strains.

Nutrient or Product	Strain 1	Strain 2	Strain 3	Strain 4
Produced biomass	0.2739	0.2618	0.2596	0.3008
carbon dioxide	1.6629	0.0110	0	5.1030
Formate	0	7.5933	7.4151	0
Hydrogen	0	0	6.0448	9.7603
Hydrogen sulfide	0	1.0653	0	0
Indole-3-propionate	0.9851	0	0	0
Isocaproate	0.8820	0	0	0

Panel 7 - Manage Case: Shows case folder and state file information.

Example – Determine an anaerobic glucose minimal medium for a 4-species community consisting of the gut pathogen *Clostridioides difficile* and three Enterobacteriaceae species

1. Select metabolic models for the strains of interest. The designed medium will ensure monoculture growth of all selected strains.

2. Define core nutrients contained in the desired medium. The core nutrients are common media components such as inorganic salt ions.

The screenshot displays the MATLAB App interface for 'MediumFBA - Integrated Medium Design and Flux Balance Analysis for Genome-Scale Metabolic Models'. The interface is divided into four main panels, each with a status indicator at the bottom.

Panel 1 - Select Strains: This panel allows users to select metabolic models. It includes a 'Model Folder' field (C:/Users/micha/OneDrive/Documents/Consulting/ISF/Matlab/GSM/AGOR), a 'Strain Model List' dropdown (Escherichia_coli_str_K_12_substr_MG1655), and a 'Filter Strains' field. Below these are buttons for 'Add Strain', 'Remove Strain', and 'Clear Strains'. A table lists selected strains with their model names, numbers, gene counts, and metabolite counts.

Strain Model	Number	Genes	Metabolites
Clostridium_difficile_CD196	1	899	1170
Enterobacter_cloacae_EcWSU1	2	1325	1414
Escherichia_coli_str_K_12_substr_MG1655	3	1190	1348
Klebsiella_pneumoniae_pneumoniae_MGH78578	4	1393	1379

Panel 2 - Define Core Medium: This panel is used to define core nutrients. It features a 'Medium Folder' field (C:/Users/micha/OneDrive/Documents/Consulting/ISF/Matlab/GrowthMedi...), a 'Core Medium List' dropdown, a 'Core Nutrient List' dropdown (Ammonium), and a 'Filter Core Nutrients' field. Buttons for 'Add Core Nutrient', 'Remove Core Nutrient', and 'Clear Core Nutrients' are present. A table lists core nutrients with their uptake bounds and the strains they support.

Core Nutrient	Uptake Bound	Strains Transporter
Ammonium	-1000	1 2 3 4
Chloride	-1000	1 2 3 4
Co2+	-1000	1 2 3 4
Cu2+	-1000	1 2 3 4
Fe2+	-1000	1 2 3 4
Fe3+	-1000	1 2 3 4
Mn2+	-1000	1 2 3 4
Sodium	-1000	1 2 3 4

Panel 3 - Define Medium Design Constraints: This panel is used to define constraints on the medium. It includes a 'Constrained Nutrient List' dropdown, a 'Filter Constrained Nutrients' field, and buttons for 'Include Nutrient', 'Exclude Nutrient', and 'Clear Nutrient'. Below are two tables for 'Included Nutrient' and 'Excluded Nutrient', each with columns for 'Uptake Bound' and 'Strains Transporter'.

Panel 4 - Design Growth Medium: This panel is used to design the growth medium. It includes an 'LP Solver' dropdown (gurobi), a 'Force Full Medium Design' checkbox, a 'Minimum Allowable Growth Rate' field (0.1), and a 'Design Medium' button. Below are buttons for 'Add Design Result', 'Remove Design Result', and 'Clear Design Table'. A table is provided for 'Growth Nutrient' with columns for 'Strain 1', 'Strain 2', 'Strain 3', and 'Strain 4'.

3. Impose constraints on the medium design solution. Nutrients can be included or excluded according to their suitability as medium components.

4. Design the growth medium by ensuring monoculture growth. The constraints can be altered in an iterative manner to generate an acceptable set of growth nutrients.

MATLAB App

MediumFBA - Integrated Medium Design and Flux Balance Analysis for Genome Scale Metabolic Models

1 - Select Strains

Model Folder: C:/Users/micha/OneDrive/Documents/Consulting/ISF/Matlab/GSM/AGOR

Strain Model List: Escherichia_coli_str_K_12_substr_MG1655

Filter Strains:

[Add Strain](#) [Remove Strain](#) [Clear Strains](#)

Strain Model	Number	Genes	Metabolites
Clostridium_difficile_CD196	1	899	1170
Enterobacter_cloacae_EcWSU1	2	1325	1414
Escherichia_coli_str_K_12_substr_MG1655	3	1190	1348
Klebsiella_pneumoniae_pneumoniae_MGH78578	4	1393	1379

[Build Metabolic Model](#) Panel 1 Status: [Metabolic Model Build Complete](#)

2 - Define Core Medium

Medium Folder: C:/Users/micha/OneDrive/Documents/Consulting/ISF/Matlab/GrowthMedi

Core Medium List: Basic_ions_agora

Core Nutrient List: Ammonium

Filter Core Nutrients:

[Add Core Nutrient](#) [Remove Core Nutrient](#) [Clear Core Nutrients](#)

Core Nutrient	Uptake Bound	Strains Transporter
Ammonium	-1000	1 2 3 4
Chloride	-1000	1 2 3 4
Co2+	-1000	1 2 3 4
Cu2+	-1000	1 2 3 4
Fe2+	-1000	1 2 3 4
Fe3+	-1000	1 2 3 4
Mn2+	-1000	1 2 3 4
Sodium	-1000	1 2 3 4

[Save Core Medium](#) Core File:

[Set Core Medium](#) Panel 2 Status: [Core Medium Transferred](#)

3 - Define Medium Design Constraints

Constrained Nutrient List: D-glucose

Filter Constrained Nutrients:

[Include Nutrient](#) [Exclude Nutrient](#) [Clear Nutrient](#)

Included Nutrient	Uptake Bound	Strains Transporter
Ammonium	-1000	1 2 3 4
Chloride	-1000	1 2 3 4
Co2+	-1000	1 2 3 4
Cu2+	-1000	1 2 3 4
D-glucose	-5	1 2 3 4

Excluded Nutrient	Uptake Bound	Strains Transporter
O2	0	1 2 3 4

[Set Medium Constraints](#) Panel 3 Status: [Medium Constraints Set](#)

4 - Design Growth Medium

LP Solver: gurobi Force Full Medium Design

Minimum Allowable Growth Rate: 0.1 [Design Medium](#)

Design Strains: Clostridium_difficile_CD196

[Add Design Result](#) [Remove Design Result](#) [Clear Design Table](#)

Growth Nutrient	Strain 1	Strain 2	Strain 3	Strain 4
proton	12.4190	-992.5885	-31.6608	13.4887
sulfate	-0.4521	-0.1829	-90.0652	-0.0811
L-leucine	-1000	-0.3734	-5.4497	-0.1319
(R)-Pantothenate	-0.0329	-0.0050	-0.1940	-0.0047
Pyridoxine	-0.0165	-0.0025	-0.0970	-0.0023
L-tryptophan	-0.1130	-997.9106	-1000	-0.0166
L-valine	-15.2275	-0.2856	-5.1135	-0.1238

[Save Growth Medium](#) Growth File:

[Set Growth Medium](#) Panel 4 Status: [Medium Design Complete](#)

Type here to search

Analysis for Genome-Scale Metabolic Models

3 - Define Medium Design Constraints

Selected Nutrient List: D-glucose

Unconstrained Nutrients

Include Nutrient Exclude Nutrient Clear Nutrient

Selected Nutrient	Uptake Bound	Strains	Transporter
Glucose	-1000	1 2 3 4	
Glucose	-1000	1 2 3 4	
Glucose	-1000	1 2 3 4	
Glucose	-1000	1 2 3 4	
Glucose	-5	1 2 3 4	

Selected Nutrient	Uptake Bound	Strains	Transporter
Glucose	0	1 2 3 4	

Panel 3 Status: Medium Constraints Set

4 - Design Growth Medium

Solver: gurobi Force Full Medium Design

Maximum Allowable Growth Rate: 0.1 Design Medium

Strains: Clostridium_difficile_CD196

Design Result Remove Design Result Clear Design Table

Nutrient	Strain 1	Strain 2	Strain 3	Strain 4
Glucose	12.4190	-992.5885	-31.6608	13.4887
Glucose	-0.4521	-0.1829	-90.0652	-0.0811
Glucose	-1000	-0.3734	-5.4497	-0.1319
Glucose	-0.0329	-0.0050	-0.1940	-0.0047
Glucose	-0.0165	-0.0025	-0.0970	-0.0023
Glucose	-0.1130	-997.9106	-1000	-0.0166
Glucose	-15.2275	-0.2856	-5.1135	-0.1238

Growth Medium Growth File

Panel 4 Status: Growth Medium Transferred

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5 - Refine Growth Medium

Refined Medium List

Refined Nutrient List: L-leucine

Filter Refined Nutrients

Add Refined Nutrient Remove Refined Nutrient Clear Refined Nutrients

Refined Nutrient	Uptake Bound	Strains	Transporter
L-leucine	-1	1 2 3 4	
L-tryptophan	-1	1 2 3 4	
L-valine	-1	1 2 3 4	
Mn2+	-1000	1 2 3 4	
Pyridoxine	-1000	1 2 3 4	
Sodium	1000	1 2 3 4	

Save Refined Medium Refined File

Set Refined Medium Panel 5 Status: Refined Medium Set

6 - Simulate Refined Medium

Simulate Medium Simulation Strains: Clostridium_difficile_CD196

Add Simulation Result Remove Simulation Result Clear Simulation Table

Nutrient or Product	Strain 1	Strain 2	Strain 3	Strain 4
Produced biomass	0.2739	0.2618	0.2596	0.3008
carbon dioxide	1.6629	0.0110	0	5.1030
Formate	0	7.5933	7.4151	0
Hydrogen	0	0	6.0448	9.7603
Hydrogen sulfide	0	1.0653	0	0
Indole-3-propionate	0.9851	0	0	0
Isocaproate	0.8820	0	0	0

Panel 6 Status: Refined Medium Simulation Complete

7 - Manage Case

Case Folder: C:/Users/micha/OneDrive/Documents/Consulting/ISF/Matlab/Growth/

Save Results Results File

Save State State File: State_final_CDI_4_species_in_vitro_community

Load State Panel 7 Status: State File Created

5. Refine growth medium by modifying uptake bounds and adding non-essential nutrients such as other sugars and amino acids.

6. Simulate monoculture growth in the refined medium. FBA predicts the growth rate, nutrient uptake rates and product secretion rates of each strain.

7. Manage case by saving results and the current App state and by loading previously stored states.

Glucose Minimal Medium for Metabolic Model of 5-species *C. difficile*/Enterobacteriaceae Community

Core Nutrients Specified

Ammonium	Water
Chloride	Zinc
Co ²⁺	calcium(2+)
Cu ²⁺	hydrogenphosphate
Fe ²⁺	magnesium
Fe ³⁺	potassium
Mn ²⁺	proton
Sodium	sulfate

Growth Nutrients Included

D-glucose

Growth Nutrients Excluded

O₂

Amino Acids Identified

L-leucine
L-tryptophan
L-valine

Other Nutrients Identified

(R)-Pantothenate
Pyridoxine