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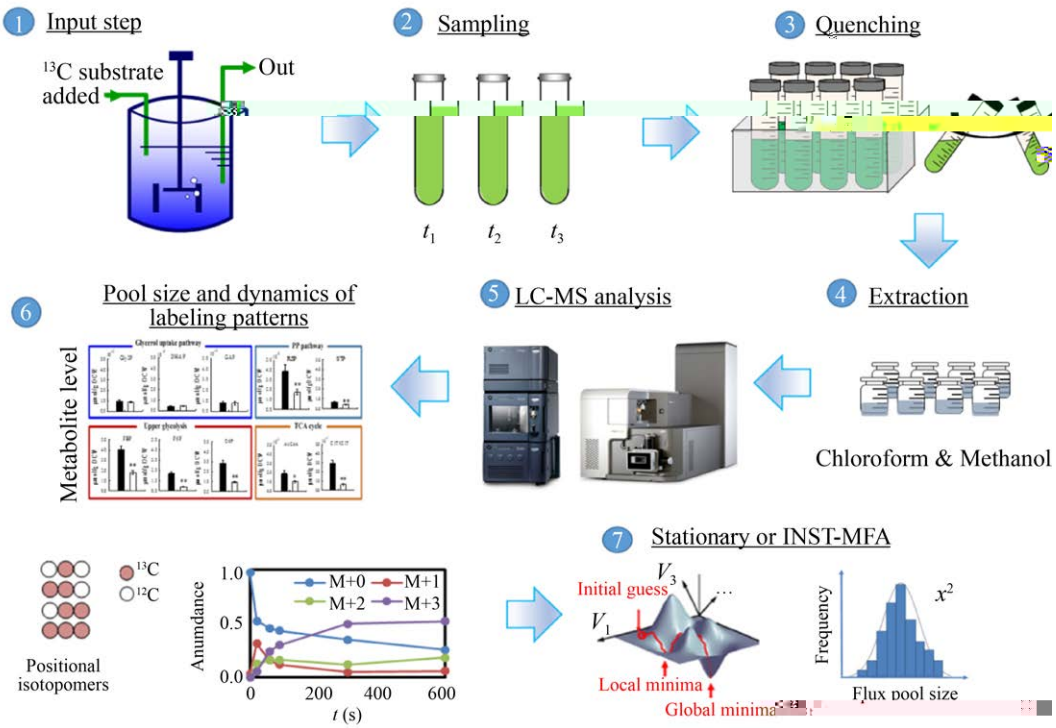
2021-02-24



1 ^{13}C

Fig. 1 ^{13}C metabolic flux analysis platform.

^{13}C 4 [28-29] (1) 3.2

(2) (3)

(4) M+1 1

^{13}C 1 ^{2}H

1 ^{17}O

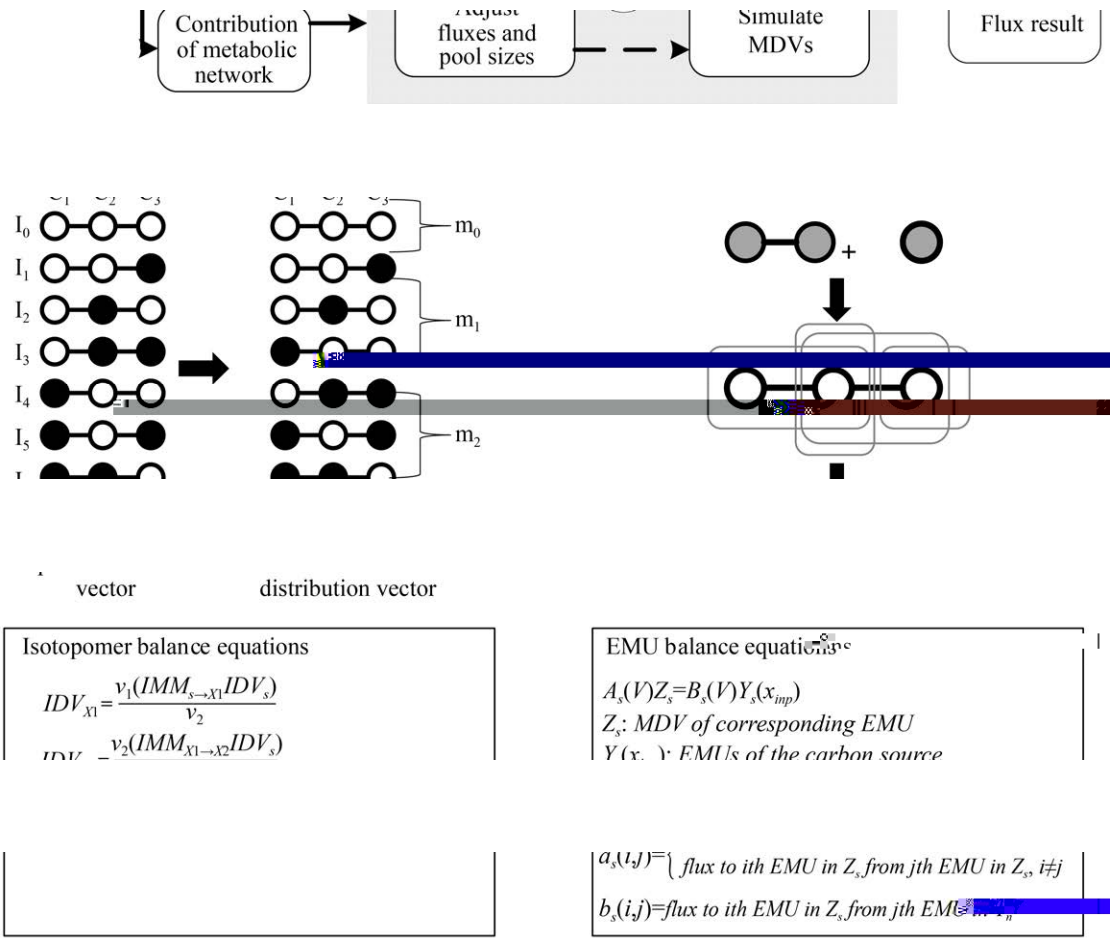
/

D- [33-34]

[31-32] ^{13}C

[28]

(Mass distribution vector MDV) [35] (2)



2

Fig. 2 A schematic view of the algorithm for the isotopomer and elementary metabolite units.

2 ^{13}C 代谢流量分析的发展历程

2.1

^{13}C

1980

1980

^{13}C

[36]

(3)

2.2

[37] *n*

2^n [38]

2D [^{13}C, ^{1}H] COSY NMR [39]

- (Gas chromatography-mass spectrometry GC-MS)

[40]

^{13}C-MFA

^{13}C-MFA

(http://www.nist.gov/srd/nist1a.cfm)

^{13}C-MFA

- (Capillary electrophoresis-mass spectrometry CE-MS)

[41] -

- (Liquid chromatography-mass spectrometry LC-MS)

[42]

GC-MS

^{13}C

[43-44]

2.3 ^{13}C

[45] [27]

[46]

20

90 Isotopomer

(Atom mapping matrix AMM)

(Isotopomer mapping matrix IMM)

[38,47] [46]

(2)

[48]

[49] (Cumomer) [50] (Bondomer)

[51] (Cumulative bondomer)

[52] (Elementary metabolite units EMU)

EMU

(2)

100 s EMUs *vs.* 1 000 s isotopomers Cumomer Cumulative bondomer 2D [^{13}C, ^{1}H] COSY NMR Isotopomer EMU NMR MS

[53-60]

^{13}C

^{13}C

(1)

-

^{13}C

1 ^{13}C-MFA

Table 1 Summary of the softwares for ^{13}C-MFA

Software	Isotopomer method	Statistical analysis	Programming language	References
13CFLUX	Isotopomer	Linear	C++	[53]
13CFLUX2	Cumomer/EMU	Linear/Monte Carlo	C++	[54]
OpenFlux	EMU	Non-linear search/Monte Carlo	Matlab	[56]
OpenFlux2	EMU	Linear/Monte Carlo	Matlab	[57]
influx_s	Cumomer/EMU	Linear/Monte Carlo	R&Python	[58]
INCA	EMU	Non-linear search/Monte Carlo	Matlab	[59]
OpenMebius	EMU	Non-linear search	Matlab	[60]
Metran	EMU	Non-linear/Monte Carlo	Matlab	[29]

2.4 ^{13}C

^{13}C

^{13}C

^{13}C [65-66] ^{13}C

^{13}C ^{13}C

[66]

2.4.1 ^{13}C

Nöh [65] ^{13}C

^{13}C

16 s 11

[61]

^{13}C FLUX/INST

Young [67] EMU

[42,62]

^{13}C ^{13}C

[10,63-64]

INCA[59]

2.4.2 ^{13}C

[11,68-69]

^{13}C

2.4.3 ^{13}C

(

)

^{13}C

^{13}C-MFA

Cordova [70] ([1,6-^{13}C]) ([5-^{13}C]) ([1,6-^{13}C]) ([5-^{13}C]) -

Yao [10] [1-^{13}C] [1,3-^{13}C] [1-^{13}C] [1,3-^{13}C] [1-^{13}C] ([

4%–6%

Faubert [75]

^{13}C

NCC 575 TCA

96%

2.5 ^{13}C

^{13}C

TCA

^{13}C

Okahashi [73] GC-NCI-MS

GC

10 mmol/L

MCF-7

Ma [68]

^{13}C-MFA

37 1 400

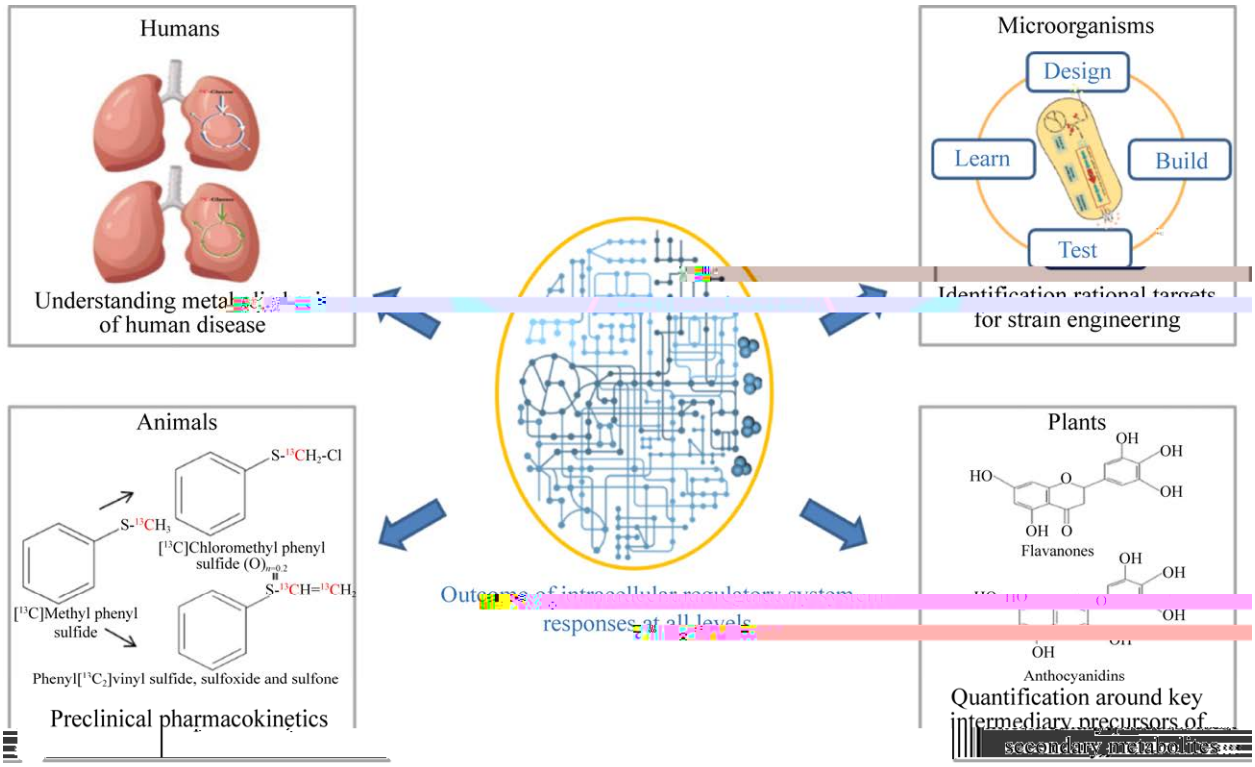
136 (54)

Liu [74]

^{13}C-MFA TCA

3 ^{13}C 代谢流量分析的应用

• 13



4 ^{13}C

Fig. 4 Applications of ^{13}C-MFA.

3.1 ^{13}C

Zhang [79] ^{15}N ^{13}C

3.1.1

-

[77]

Roell [78] ^{13}C ^{13}C -

^{13}C-MFA PD630

TCA NADPH Cui [13]

TCA

2- -3- -6- -

^{13}C-MFA TCA

) TAGs)

TAGs

TAGs TAGs

TAGs

TCA Ⅰ

( ) Ⅱ

TCA ( )

D’Espaux [16]

3.1.4

pull-push-block

A

A

- - - 1.2 g/L 6.0 g/L

3.2 ^{13}C

^{13}C

Yao [10] ^{13}C-MFA ^{13}C

NADH→NADPH [83-84]

NADPH NADPH/NADP$^+$ Spinelli [85] ^{15}N

-

nadK *pntAB* *nadK*

pntAB 65% ^{15}N

141% 208% 5

TCA

Christen [20] ^{13}C

TCA

A

TCA

Wang [82]

(Triacylglycerols

4 总结与展望

^{13}C

1) ^{13}C

[46] Zamboni[28] Long[29]

^{13}C

(

)

LC-MS Aligent Thermo Fisher Scientific SCIEX Waters Bruker

^{13}C

2)

Fischer [45]

Fischer [86]

137

^{13}C

3)

^{13}C

El Massaoudi [87] “ ”

^{13}C-MFA [88-89]

Yuan [90] GC-C-IRMS 3

^{13}C

4) ^{13}C-MFA

(Genome-scale metabolic models GEMs)

[91]

[92] Martín [92]

GEMs ^{13}C-MFA

^{13}C 30

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