Analytica Chimica Acta 902 (2016) 8–21

Contents lists available at ScienceDirect

Analytica Chimica Acta

journal homepage: www.elsevier.com/locate/aca

Review

Current analytical methods for plant auxin quantification – A review

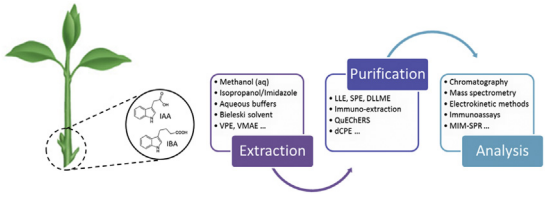
Sara Porfírio[a,c,**], Marco D.R. Gomes da Silva[b,*], Augusto Peixe[a], Maria J. Cabrita[a], Parastoo Azadi[c]

[a] Escola de Ciências e Tecnologia, Instituto de Ciências Agrárias e Ambientais Mediterrânicas - ICAAM, Universidade de Évora, 7002-554, Évora, Portugal
[b] LAQV, REQUIMTE, Departamento de Química, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516, Caparica, Portugal
[c] Complex Carbohydrate Research Center, The University of Georgia, 315 Riverbend Road, Athens, GA, 30602, USA

HIGHLIGHTS

- Recent developments in auxin analysis are covered.
- Critical review of sample preparation methods is presented.
- Extraction, purification and derivatization strategies are discussed.
- Main analytical techniques are critically compared and debated.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 22 August 2015
Received in revised form 26 October 2015
Accepted 27 October 2015
Available online 6 November 2015

Keywords:
Plant hormones
Auxins quantification
Sample preparation
Chromatographic analysis
Mass spectrometry
Immunoassays

ABSTRACT

Plant hormones, and especially auxins, are low molecular weight compounds highly involved in the control of plant growth and development. Auxins are also broadly used in horticulture, as part of vegetative plant propagation protocols, allowing the cloning of genotypes of interest. Over the years, large efforts have been put in the development of more sensitive and precise methods of analysis and quantification of plant hormone levels in plant tissues. Although analytical techniques have evolved, and new methods have been implemented, sample preparation is still the limiting step of auxin analysis. In this review, the current methods of auxin analysis are discussed. Sample preparation procedures, including extraction, purification and derivatization, are reviewed and compared. The different analytical techniques, ranging from chromatographic and mass spectrometry methods to immunoassays and electrokinetic methods, as well as other types of detection are also discussed. Considering that auxin analysis mirrors the evolution in analytical chemistry, the number of publications describing new and/or improved methods is always increasing and we considered appropriate to update the available information. For that reason, this article aims to review the current advances in auxin analysis, and thus only reports from the past 15 years will be covered.

Contents

* Corresponding author.
** Corresponding author. Escola de Ciências e Tecnologia, Instituto de Ciências Agrárias e Ambientais Mediterrânicas- ICAAM, Universidade de Évora, 70062-554, Évora, Portugal; IIFA, Universidade de Évora, Núcleo da Mitra, Ap. 94, 7002-554 Évora, Portugal.
E-mail addresses: sporfirio@uevora.pt, porfirio@uga.edu (S. Porfírio), mdr@fct.unl.pt (M.D.R. Gomes da Silva).

http://dx.doi.org/10.1016/j.aca.2015.10.035
0003-2670/

Abbrevations

$[C_4mim][PF_6]$	1-butyl-3-methylimidazolium hexafluorophosphate
2D-GC	Two-dimensional GC
2D-HPLC	Two-dimensional HPLC
4-APBA	4-aminophenylboronic acid
ABA	Abscisic acid
AEMP	2-(2-aminoethyl)-1-methylpyrrolidine
anti-IAA	Monoclonal antibodies against IAA
APF	6-Oxy-(acetyl piperazine) fluorescein
AuNPs	Gold nanoparticles
BHT	Butylated hydroxytoluene
BSA	Bovine serum albumin
BTA	3-bromoactonyltrimethylammonium bromide
CE	Capillary electrophoresis
CEC	Capillary electrochromatography
CE-ECL	CE coupled with electrochemiluminescent detection
CE-LIF	CE coupled with laser-induced fluorescence detection
CNT	Carbon nanotube
CZE	Capillary zone electrophoresis
DAD	Diode array detector
DCC	N,N′-dicyclohexylcarbodiimide
dCPE	Dual-cloud point extraction
DLLME	Dispersive liquid-liquid microextraction
DPV	Differential pulse voltammetry
ELISA	Enzyme-linked immunosorbent assay
EOF	Electroosmotic flow
FLD	Fluorescence detector
FW	Fresh weight
GC	Gas chromatography
GC-ECD	GC coupled with electron capture detection
GC-FID	GC coupled with flame ionization detector
HF-LLLME	Hollow fiber-based liquid-liquid-liquid microextraction
HOOBt	3,4-dihydro-3-hydroxy-4-oxo-1,2,3-benzotriazine
HRP-IgGs	HRP-labeled immunoglobulins
IAA	Indole-3-acetic acid
IAA-Asp	IAA-Aspartate
IAA-Gly	IAA-Glycine
IAA-HRP	IAA labeled with horseradish peroxidase
IAA-Inos	Auxin-*myo*-inositol conjugates
IAA-Phe	IAA-Phenylalanine
IAA-Trp	IAA-Tryptophan
IAA-Val	IAA-Valine
IBA	Indole-3-butyric acid
ICA	Indole-3-carboxylic acid
IEC	Ion exchange chromatography
IPA	Indole-3-propionic acid
IT	Ion trap
LC	Liquid chromatography
LC × LC	Comprehensive 2D-HPLC
LLE	Liquid-liquid extraction
MAE	Microwave-assisted extraction
Mag-MIPs	Magnetic MIPs
MeIAA	IAA methyl ester
MEKC	Micellar electrokinetic chromatography
MIM	Molecularly imprinted monolayer
MIMs	Molecularly imprinted microspheres
MIPs	Molecularly imprinted polymers
MISPE	Molecularly imprinted SPE
MPA-CdS/RGO	3-mercaptopropionic acid stabilized CdS/reduced graphene oxide nanocomposites
MRM	Multiple reaction monitoring
MSI	MS imaging
NAA	Naphtaleneacetic acid
PAA	Phenylacetic acid
pCEC	Pressurized capillary electrochromatography
PDA	Photodiode array detector
PDAB	*p*-(dimethylamino)benzaldehyde
PEC	Photoelectrochemical immunosensor
Q-ICR FT-MS	Quadrupole ion cyclotron resonance Fourier transform MS
QCM	Quartz crystal microbalance
qMS/MS	Tandem quadrupole MS
QTOF	Quadrupole time-of-flight
Q-Trap	Triple quadrupole linear ion trap
QuEChERS	Acronym for quick, easy, cheap, effective, rugged and safe
RI	Refractive index
RIA	Radioimmunoassay
RP	Reversed phase
SACE	Sol-gel-alginate-carbon composite electrode
SEC	Size exclusion chromatography
SIM	Selected ion monitoring
SPE	Solid-phase extraction
SPME	Solid-phase microextraction
SPR	Surface plasmon resonance
TMB	3,3′,5,5′- tetramethylbenzidine
TMOS	Tetramethoxysilane
TOF-MS	Time-of-flight mass spectrometry
VMAE	Vacuum microwave-assisted extraction
VPE	Vapor phase extraction