Innovative technologies in Food Fortification: A Bamboo perspective

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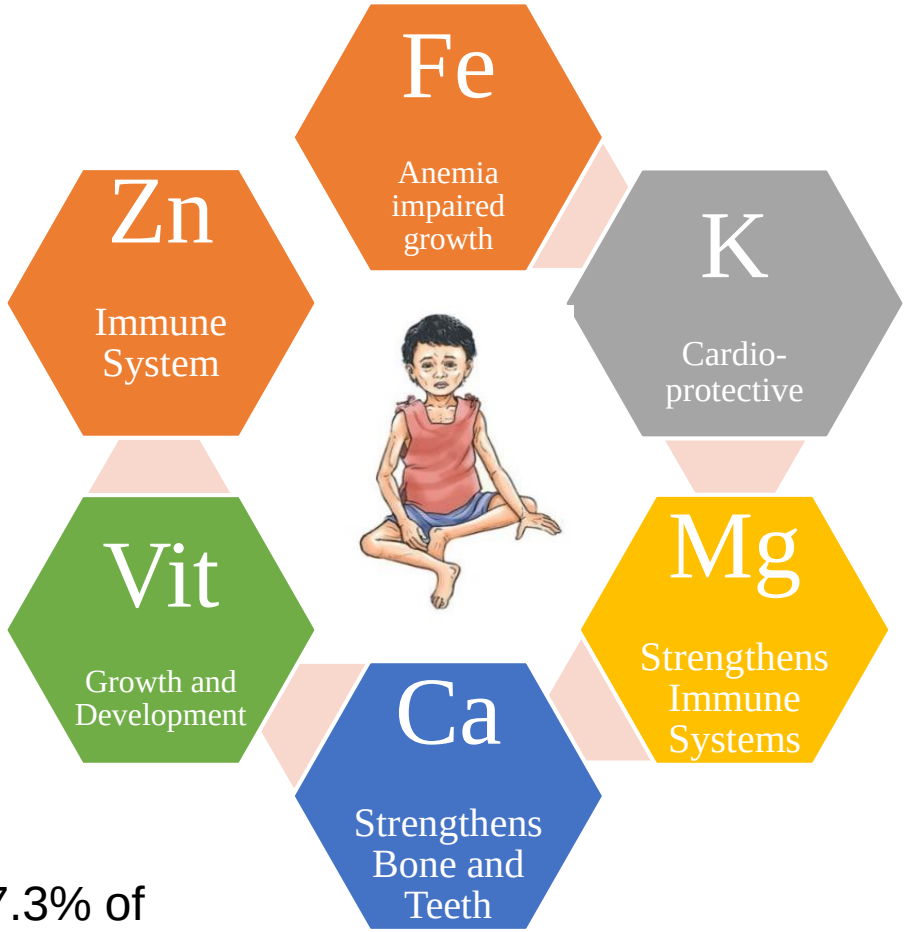
WORLD BAMBOO AMBASSADOR

Hidden Hunger: a Global burden

Globalization/Urbanization



Micronutrient deficiencies account for 7.3% of the global burden of disease

Currently, FAO estimates that around 800 million people suffer from food and nutrition insecurity, particularly in underprivileged population groups.

How to mitigate Hidden Hunger?

- **Diversification** — The quantity and the range of micronutrients rich foods can be increased
- **Supplementation** — Deliver nutrients directly to the population through nutraceuticals
- **Fortification** — Enrichment by addition of micronutrients in processed foods
- **Biofortification** — Increasing nutrient density of food crops

Why Food Fortification?

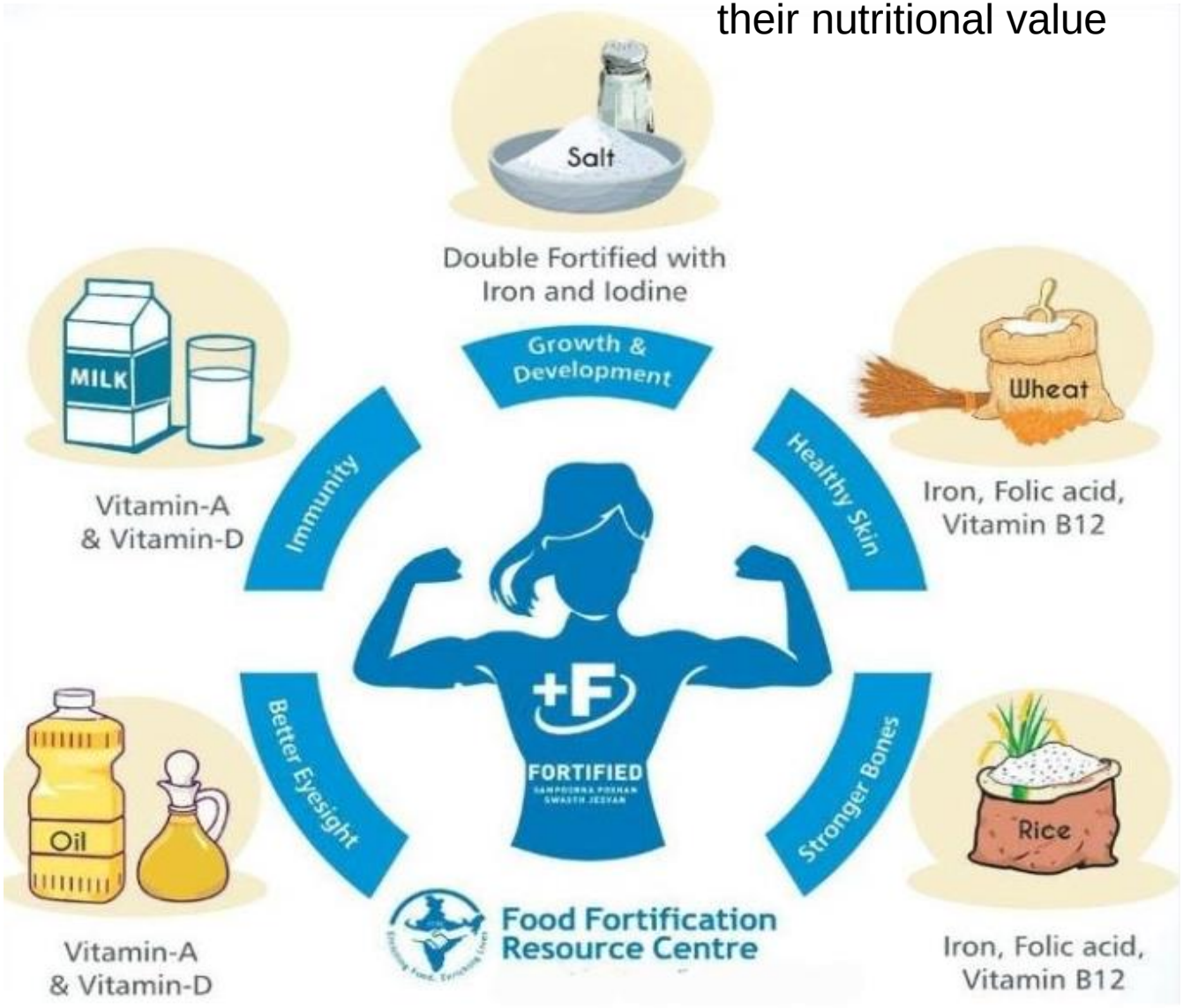
Increased food demand has led to specific intensification in agriculture practices leading to loss in crop diversity and shrinkage of the food basket

Negative consequences are malnutrition and diet related diseases

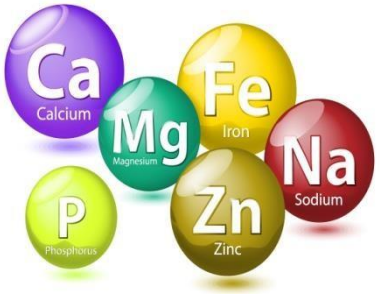
Fortification was introduced to achieve the enhancement of food functionality

Food Fortification

Enrichment of food by adding health promoting and nutrition boosting additives to consumed food to increase their nutritional value



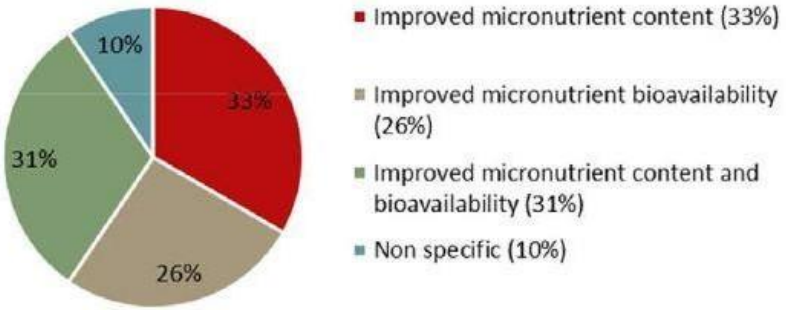
Food to Food Fortification



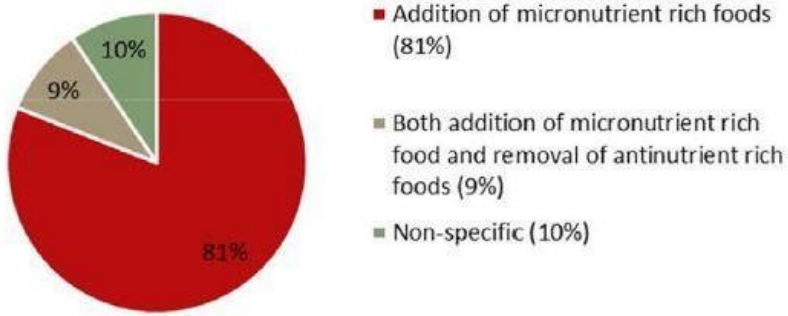
Food-to-food fortification (FtFF): an emerging component of food-based strategies, where micronutrient-dense foods are added to food products. The fortificants are typically fruits and vegetables with high vitamin and mineral content

Promote the production, access, and intake of micronutrient rich foods with the aim of enhancing the content and/or bioavailability of target nutrients, especially micronutrients

c Objective of FtFF



d Technique of FtFF



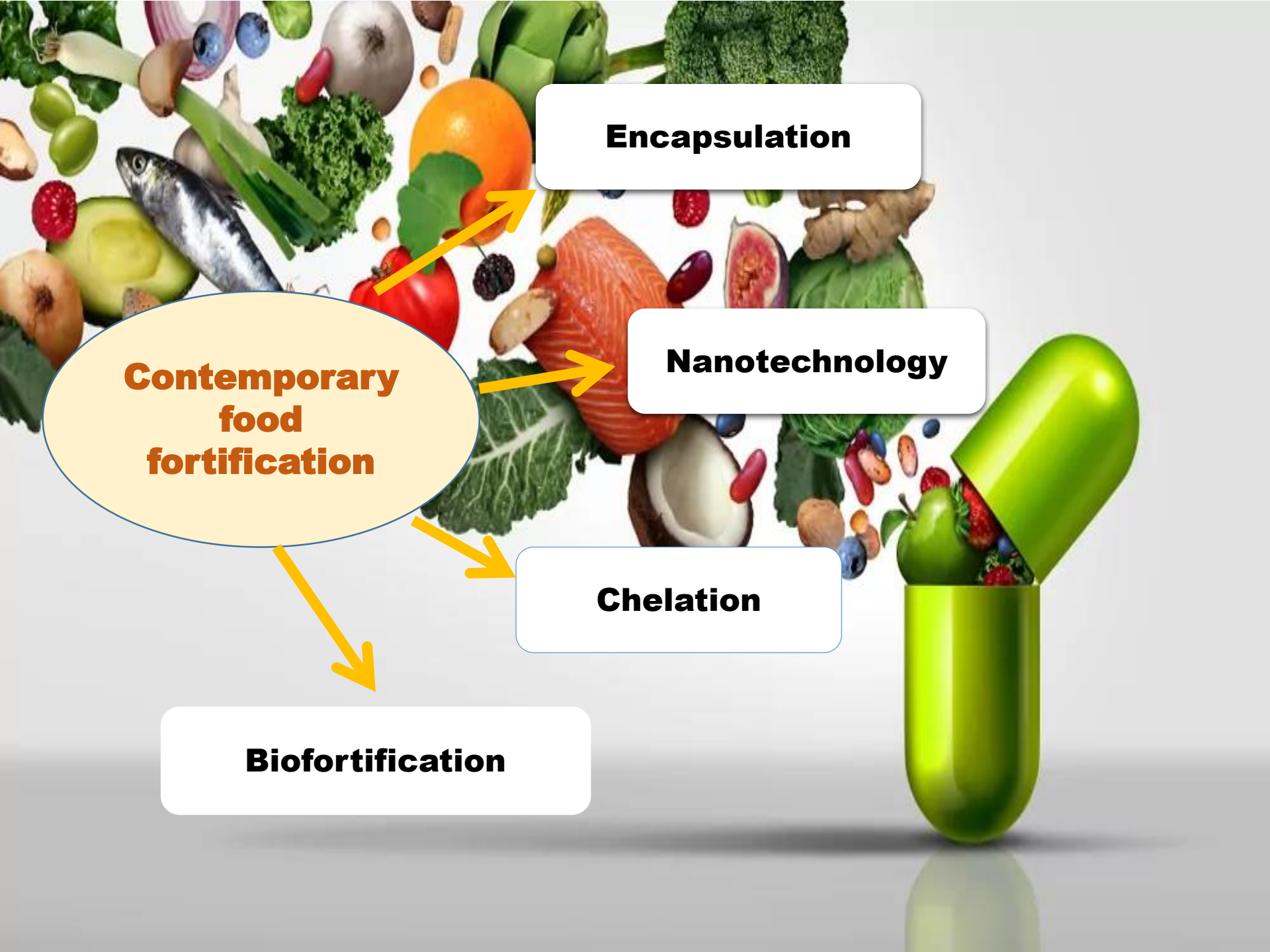
Conventional Food fortification

Fermentation

Synthetic micronutrients

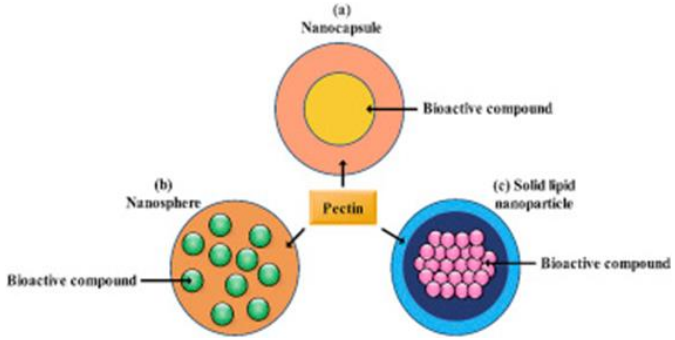
Biofortification

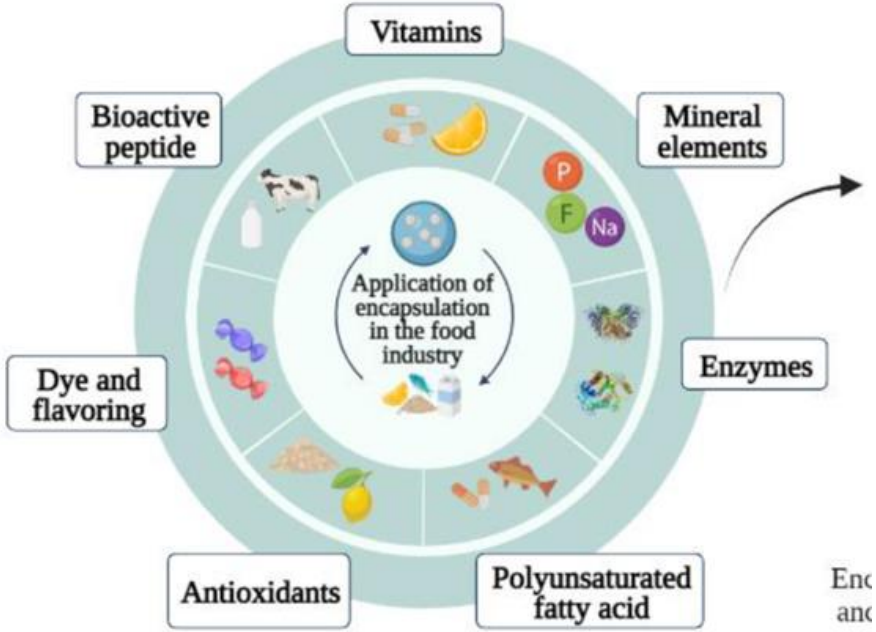
The most commonly fortified foods include salt, milk, sugar, oils and rice, wheat and maize flour.


Contemporary food fortification
Encapsulation
Nanotechnology
Chelation
Biofortification

Encapsulation

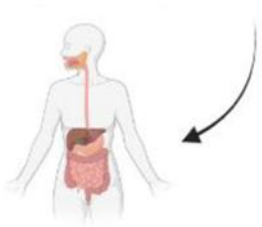
Incorporation of food ingredients, enzymes, cells or other materials in small capsules to protect the encapsulated materials from moisture, heat or other extreme conditions, thus enhancing their stability and maintaining viability





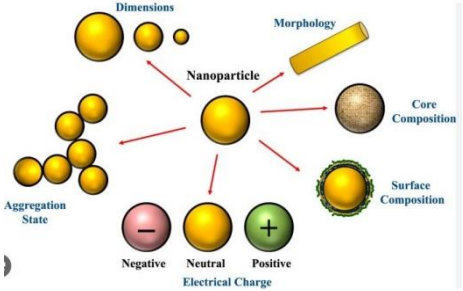
Advantages of Encapsulation

- ❖ Protection of active ingredients
- ❖ Reduction of undesirable taste, odour and colour
- ❖ Prevents unwanted reactions and interactions
- ❖ Control its release rate
- ❖ Long term storage



Encapsulation allows for better stability and bioavailability after food ingestion

Nanotechnology



Represents an innovative advance in increasing the bioavailability and efficiency of bioactive compounds in food products

Nanoscale food additives in the form of preservatives, antimicrobial sensors, packaging materials, encapsulated food components are known to influence the nutrient composition as well as improve product shelf life, flavour and texture

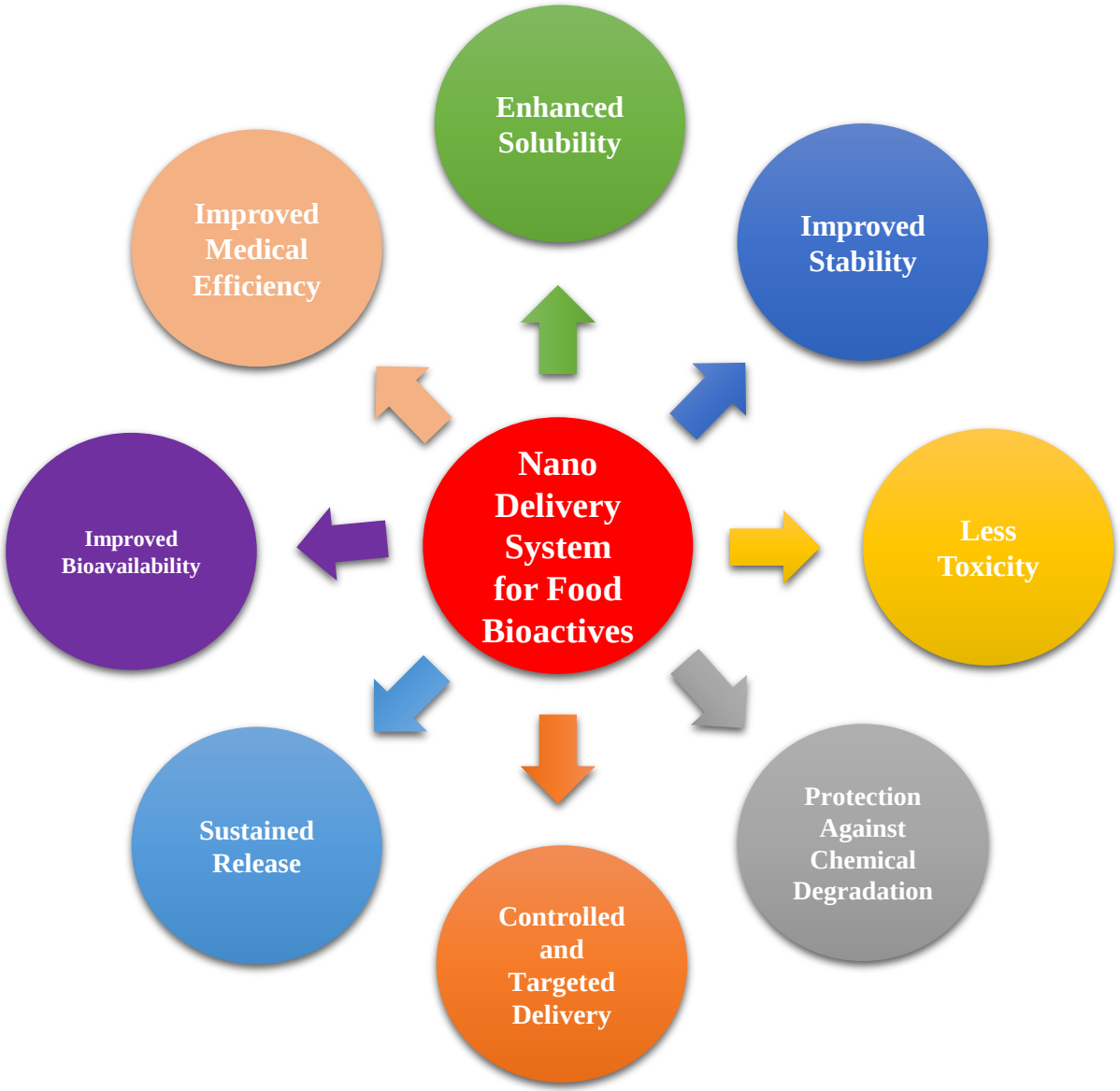
Food processing and Preservation

- Structural modification of food
- Nanoencapsulated food additives
- Nanopreservation
- Toxin detection
- Antimicrobial nanoparticles

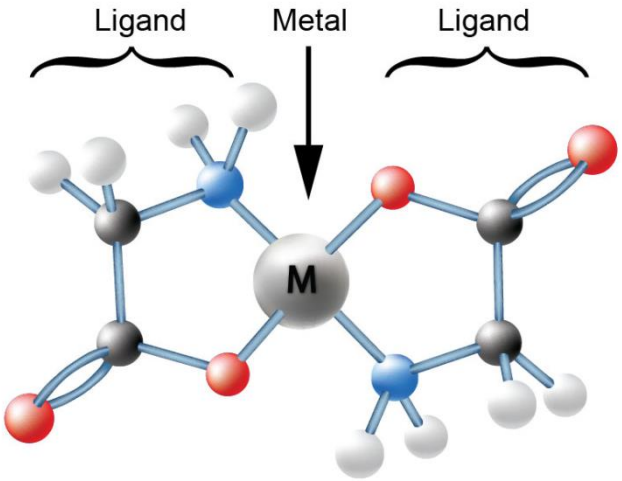
Food packaging

- Nanocoating
- Nanocomposites
- Active packaging solutions
- Edible coating nanomaterial

Nanomaterials are used as ingredients and additives (e.g., vitamins, antimicrobials, antioxidants) in nutrients and health supplements



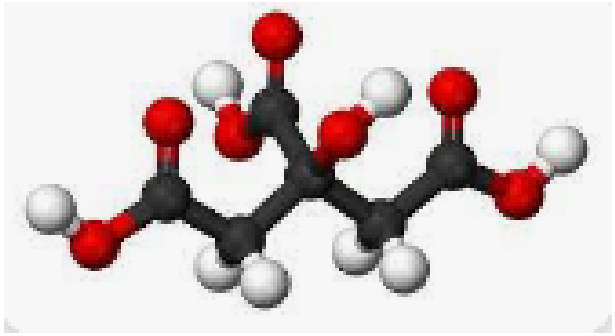
Chelation



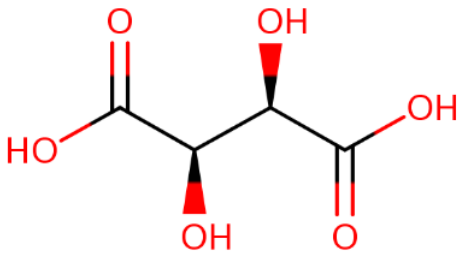
A type of bonding of ions and molecules to metal ions

Preventive antioxidants preserving the quality and extending the shelf life of various products

Chelation can hinder enzymatic browning in fruits and vegetables and spoilage in fatty foods like baked food products



Citric acid



Tartaric acid

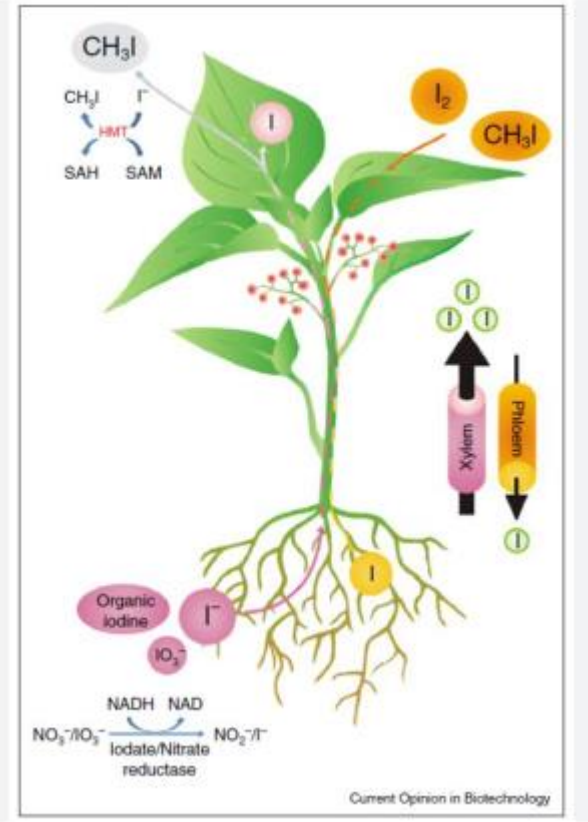
Ethylene diamine tetra acetic acid

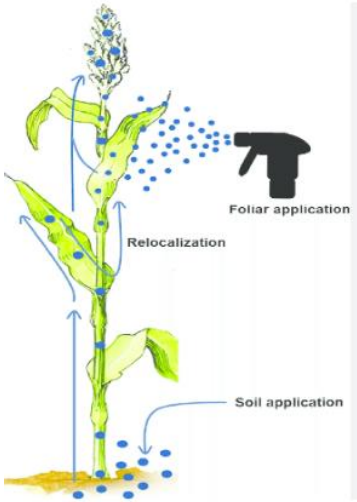
Genetic Engineering

Plant Breeding

Biofortification

Agronomic Approaches





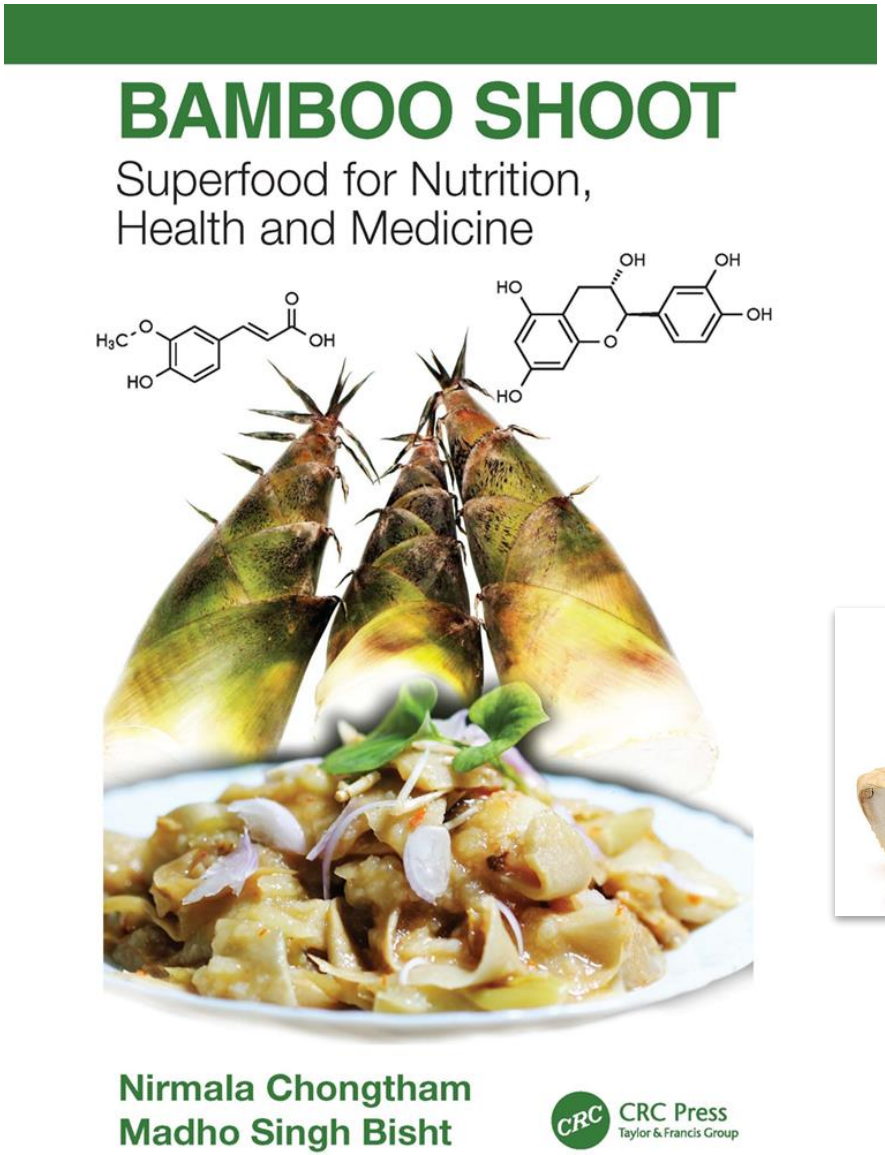
Bamboo Shoots: Powerhouse of Nutrients and Bioactive compounds!

NUTRIENTS

Proteins,
Carbohydrates,
Amino acids,
Minerals, Vitamins

BIOACTIVE COMPOUNDS

Phenols, Dietary fibre,
Phytosterols



Nutrient rich Food beneficial for Health and well being

Nutrients

Bioactive compounds

Young shoots

Peeled shoots

Harvested shoots

BAMBOO SHOOT PROCESSING

01 Sample collection

BAMBOO SHOOT

EDIBLE PORTION OF SHOOTS

BAMBOO LEAVES

02 Processing

FERMENTATION

BOILING

03 Drying

FREEZE DRYING

HOT AIR OVEN DRYING

04 Powder

GRINDER

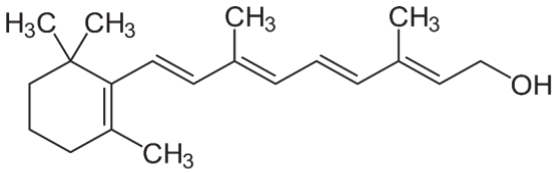
Extract Preparation

05 Biochemical Analysis

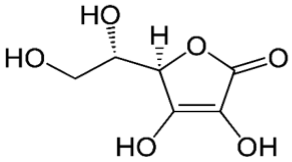
Nutritive value of bamboo shoots

- Rich in proteins, carbohydrates, amino acids, minerals, vitamins
- All 9 essential amino acids
- Minerals like K, P, Mg, Na, Fe, Ca and Se.
- Rich in dietary fibers
- Low in fat and sugar.

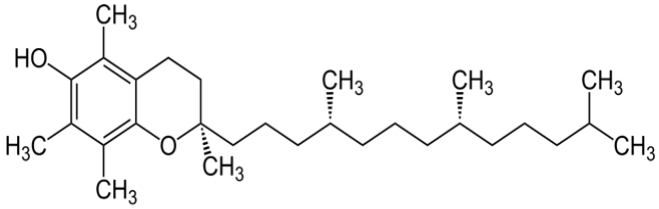
Vitamins in Bamboo shoots (mg/100g)



Vitamin A



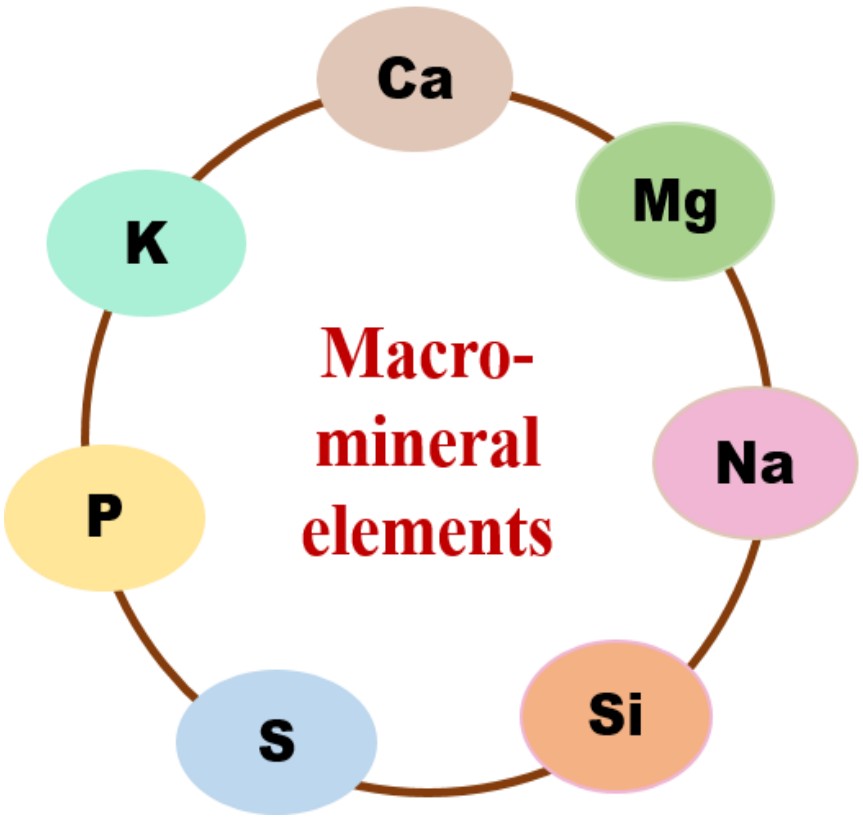
Vitamin C

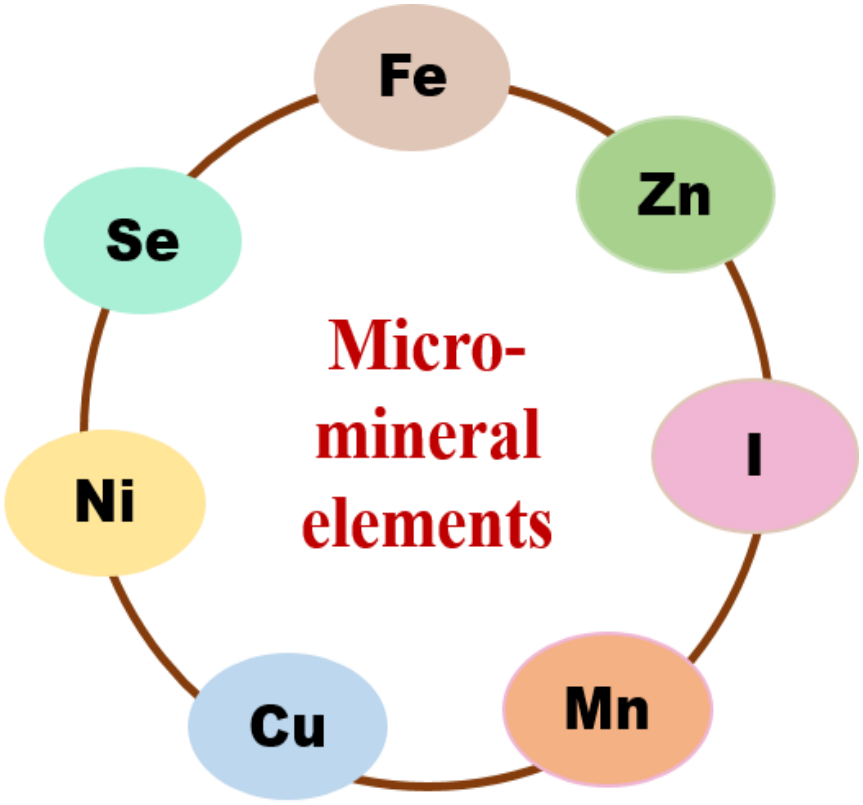


Vitamin E

Species	Vitamin A	Vitamin C	Vitamin E
B. balcooa	0.554 ± 0.001	2.63 ± 0.02	0.42 ± 0.03
B. nutans	0.561 ± 0.002	1.52 ± 0.03	0.49 ± 0.02
B. tulda	0.528 ± 0.001	1.42 ± 0.06	0.85 ± 0.13
B. vulgaris	0.539 ± 0.001	4.80 ± 0.10	0.52 ± 0.09
D. asper	0.553 ± 0.002	0.91 ± 0.13	0.95 ± 0.02
D. giganteus	0.514 ± 0.003	2.21 ± 0.02	0.56 ± 0.03
D. hamiltonii	0.542 ± 0.001	2.48 ± 0.07	0.68 ± 0.03
D. membranaceous	0.539 ± 0.002	1.83 ± 0.04	0.65 ± 0.03
D. longispathus	0.573 ± 0.001	3.08 ± 0.02	0.78 ± 0.06
T. siamensis	0.559 ± 0.001	2.80 ± 0.10	0.37 ± 0.06

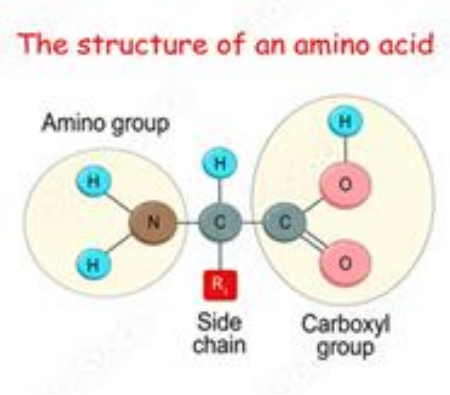
Minerals in Bamboo



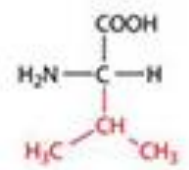


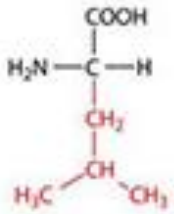
Amino acids

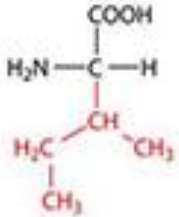
Synthesis of proteins, Precursors of secondary metabolites

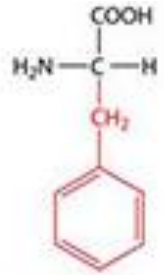


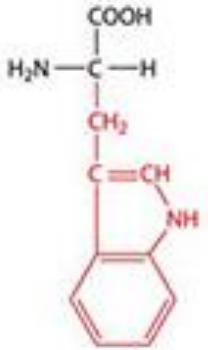
Essential amino acids

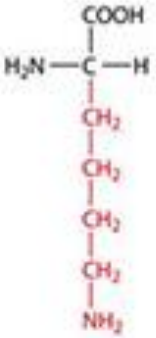

Valine

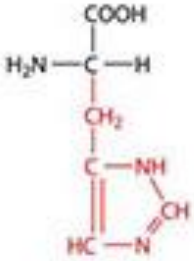

Leucine


Isoleucine

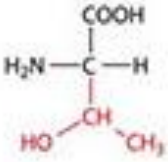

Phenylalanine


Tryptophan

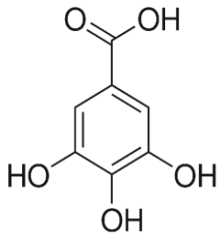

Lysine


Histidine

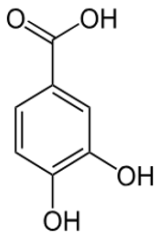

Methionine


Threonine

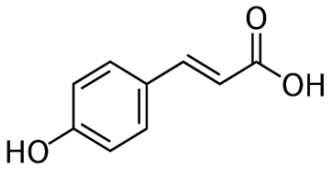
Common polyphenolic compounds in Bamboo



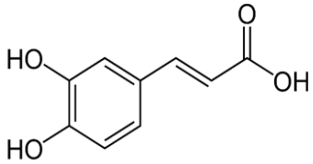
Gallic acid



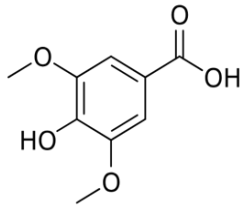
Protocatechuic acid



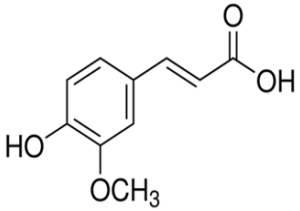
p-coumaric acid



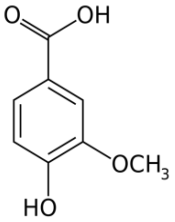
Caffeic acid



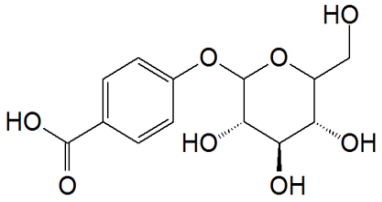
Syringic acid



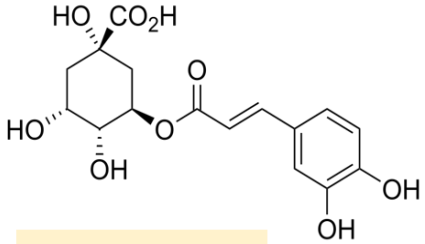
Ferulic acid



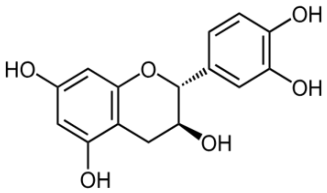
Vanillic acid



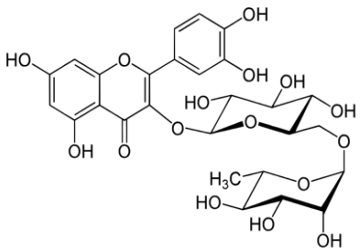
p-hydroxybenzoic acid



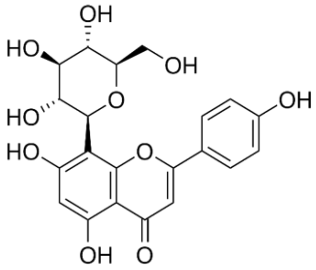
Chlorogenic acid



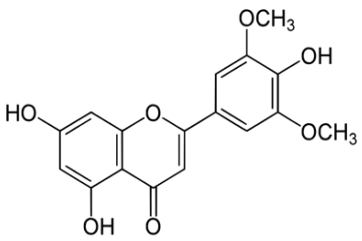
Catechin



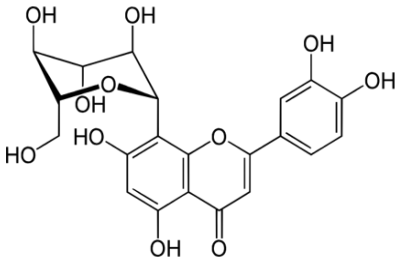
Rutin



Vitexin

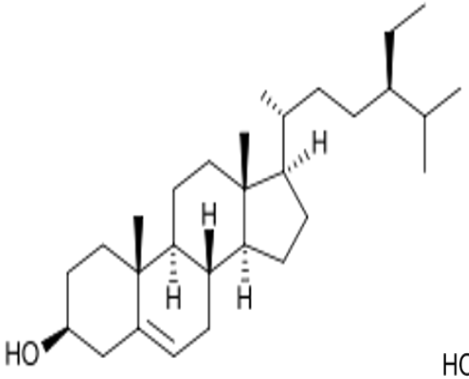


Tricin

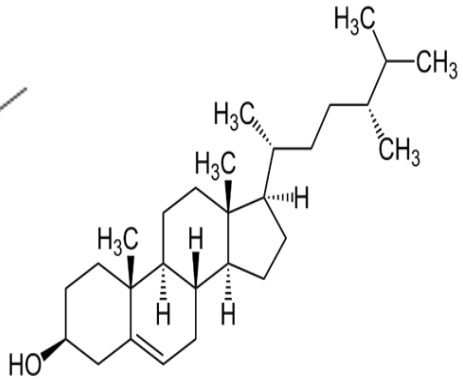


Orientin

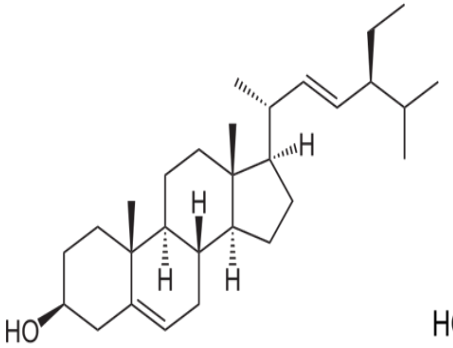
Common Phytosterols in Bamboo



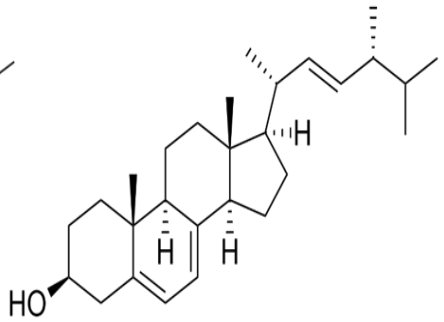
β-sitosterol



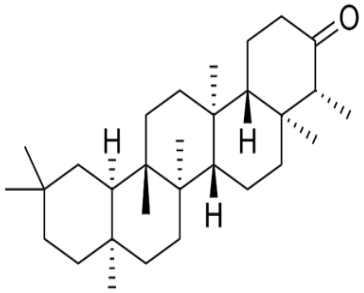
Campesterol



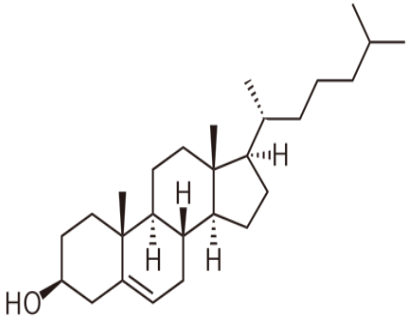
Stigmasterol



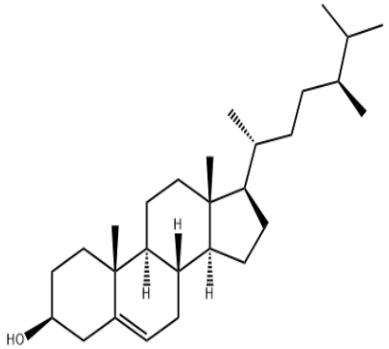
Ergosterol



Friedelin



Cholesterol



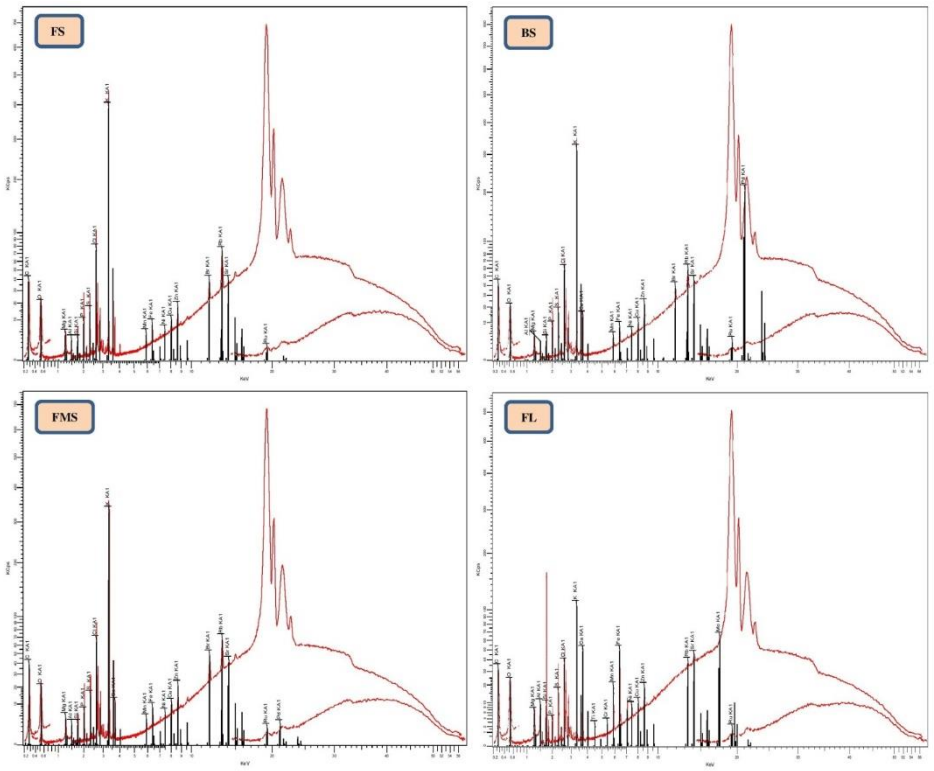
Dihydrobrassicasterol

Analytical techniques

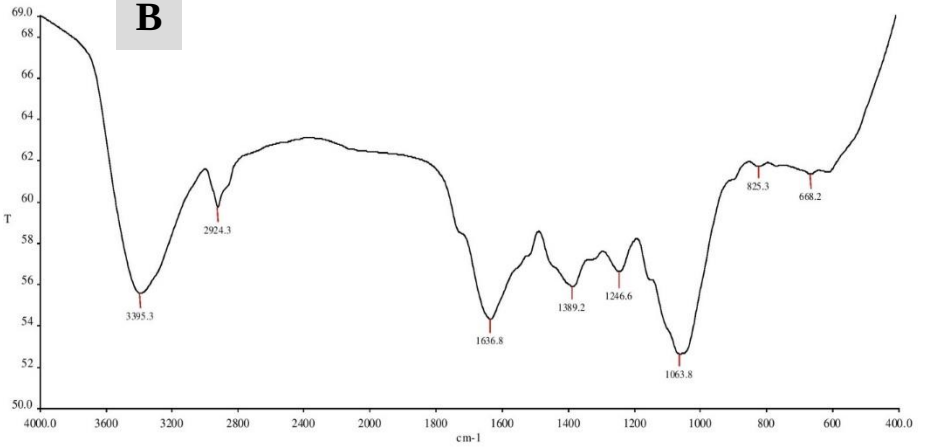
FTIR: Fourier Transform Infrared Spectroscopy
GC-MS: Gas Chromatograph Mass Spectrometry

A

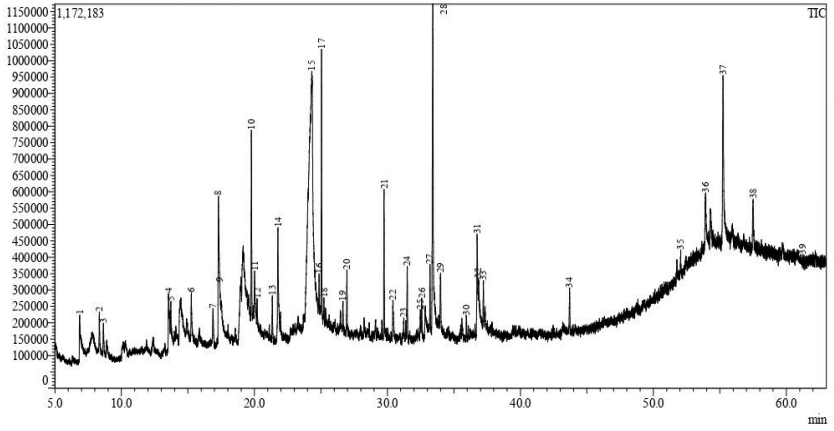
WDXRF spectrometry



B

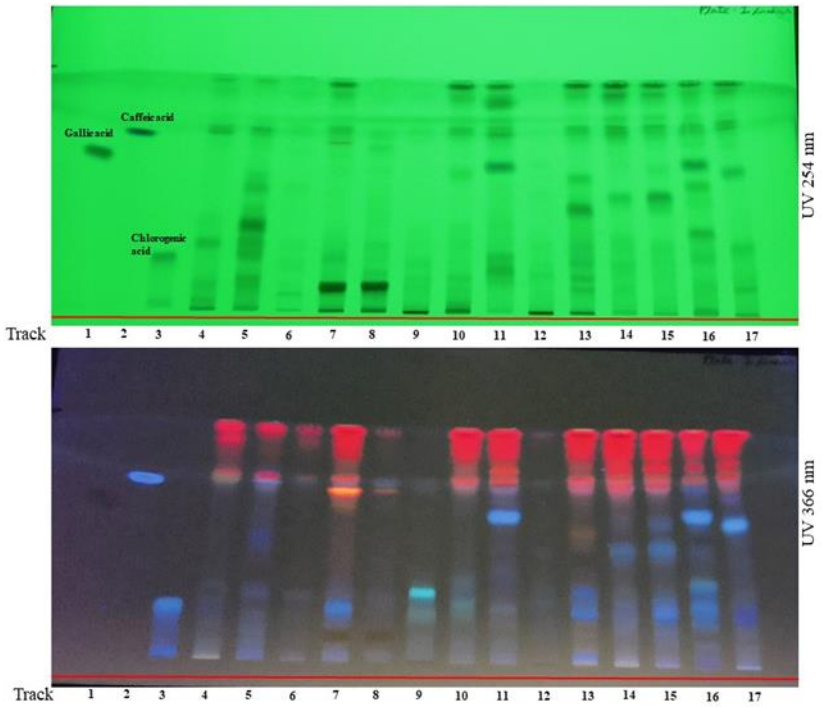


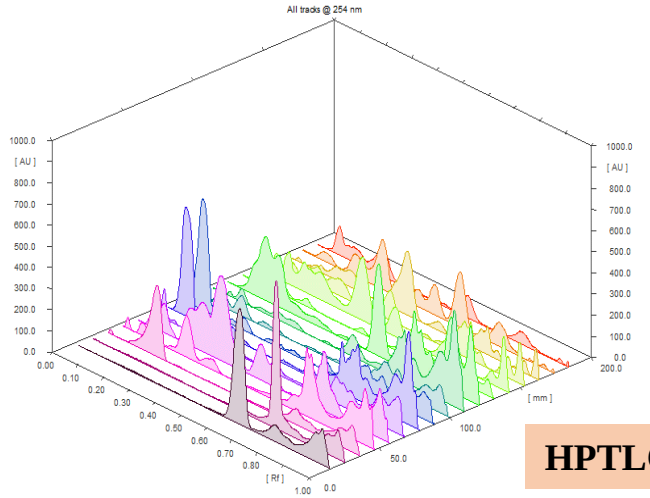
C



A: X-ray fluorescence spectra of samples [FS (Fresh shoot), BS (Boiled shoot), FMS (Fermented shoot) and FL (Fresh leaf)]; B: FTIR spectra of FS; C: GCMS spectra of FMS

High Performance Thin Layer Chromatography (HPTLC)



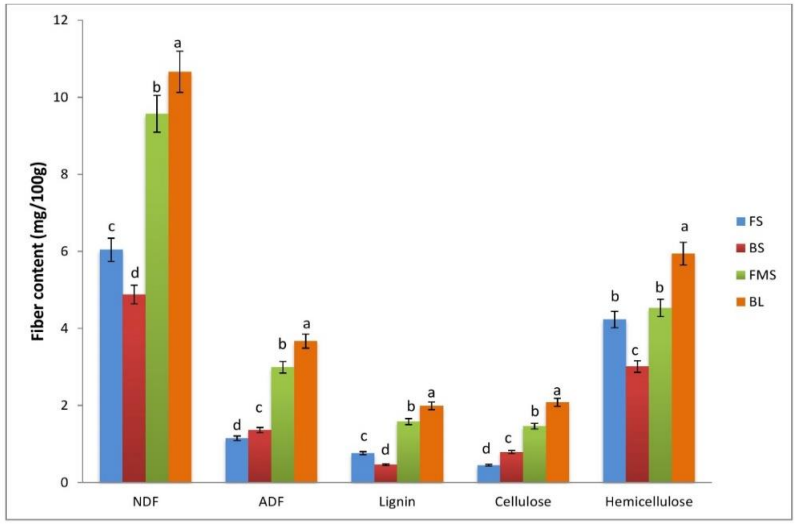


HPTLC fingerprints and densitogram

Peak	Compounds	Formula	RT (min)	Quantification (mg/100 g)			
				FS	BS	FMS	FL
1	Gallic acid	$C_7H_6O_5$	3.570	52.59	23.81	56.65	191.32
2	Caffeic acid	$C_9H_8O_4$	4.442	81.99	11.96	29.43	42.37
3	4-hydroxybenzoic acid	$C_7H_6O_3$	4.442	81.99	11.96	29.43	42.37
4	Coumaric acid	$C_9H_8O_3$	5.820	3.97	-	41.88	17.27
5	Ferulic acid	$C_{10}H_{10}O_4$	6.203	663.63	-	515.40	-
6	Rutin	$C_{27}H_{13}O_{16}$	3.827	34.75	26.57	17.53	72.38
7	Catechol	$C_6H_6O_2$	4.702	97.53	58.58	141.29	53.93
8	Naringin	$C_{27}H_{32}O_{14}$	4.702	97.53	58.58	141.29	53.93
9	Luteolin	$C_{15}H_{10}O_6$	13.273	0.44	-	2.94	-

HPLC analysis and quantification of phenolic compounds present in *B. nutans* extracts

Dietary fiber and its components in the juvenile shoots of some species (g/100g f.w.)



Dietary fiber content (mg/100 g) in FS (Fresh shoot), BS (Boiled shoot), FMS (Fermented shoot) and FL (Fresh leaf).

Sl.	Name of species	NDF	ADF	Lignin	Cellulose	Hemicellulose
1	*Bambusa balcooa*	6.07±0.04	0.51±0.02	0.30±0.02	0.21±0.01	5.56±0.06
2	*B. bambos*	3.95±0.12	0.48±0.01	0.30±0.02	0.18±0.00	3.47±0.06
3	*B. nutans*	5.34±0.14	1.17±0.05	0.78±0.01	0.40±0.02	4.17±0.08
4	*B. tulda*	4.62±0.02	0.80±0.03	0.54±0.04	0.26±0.04	3.82±0.09
5	*B. vulgaris*	4.24±0.01	3.28±0.02	2.40±0.01	0.78±0.01	0.96±0.09
6	*Dendrocalamus asper*	3.54±0.06	3.00±0.01	1.26±0.01	1.74±0.00	0.47±0.05
7	*D. giganteus*	5.60±0.02	0.83±0.01	0.49±0.04	0.34±0.02	4.77±0.14
8	*D. hamiltonii*	4.78±0.06	0.94±0.02	0.68±0.05	0.26±0.02	3.84±0.09
9	*D. hookeri*	5.01±0.05	1.03±0.02	0.11±0.03	0.92±0.06	3.97±0.03
10	*D. latiflorus*	5.88±0.01	0.87±0.03	0.44±0.02	0.43±0.02	5.01±0.04
11	*D. longispathus*	4.42±0.12	0.68±0.01	0.36±0.04	0.32±0.04	3.74±0.13
12	*D. manipureanus*	7.40± 0.02	0.63±0.02	0.21±0.04	0.42±0.03	6.77±0.02
13	*D. membranaceus*	5.33±0.12	1.93±0.07	0.37±0.03	1.56±0.06	3.40±0.04
14	*Melocanna baccifera*	4.32±0.14	0.61±0.03	0.16±0.03	0.45±0.04	3.71±0.12
15	*Phyllostachys mannii*	5.72±0.03	1.41±0.05	0.17±0.01	1.24±0.01	4.31±0.03

Values reported are measurement replication means ± standard deviation (n = 3 replicates)

Traditional Indian dishes

Traditional bamboo shoot cuisines

Japan

Thailand

Philippines

Malaysia

Korea

China

Fortification with bamboo shoots

Bamboo shoots rich in nutrients and bioactive compounds are an attractive food resource for developing fortified food products

Processed shoots – boiled dried and fermented shoots are used

Nutrients decrease during processing but bioactive compounds such as phenols, phytosterols and dietary fibers are increased which is good for health

Fortified bamboo shoot products have enormous potential as a health food and a good source for nutraceutical and pharmaceutical products

Bamboo Fortified Food products

Bamboo Fortified

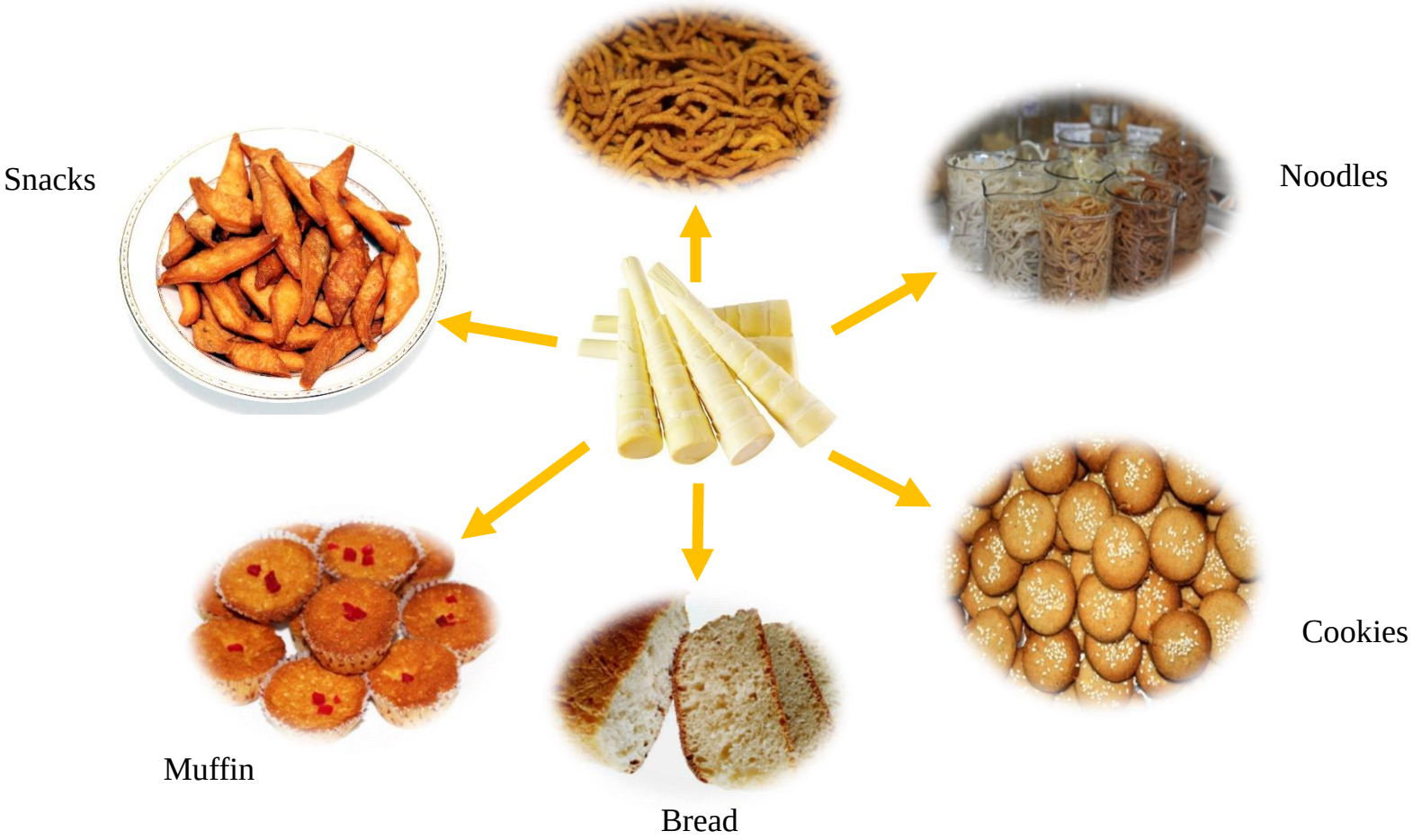
Dietary fibre from Bamboo

Vitacel Bamboo fiber

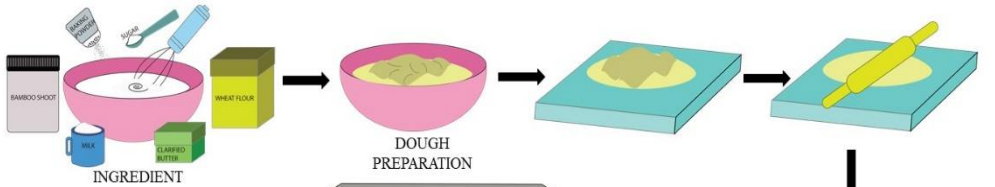
Sanacel Bamboo fiber

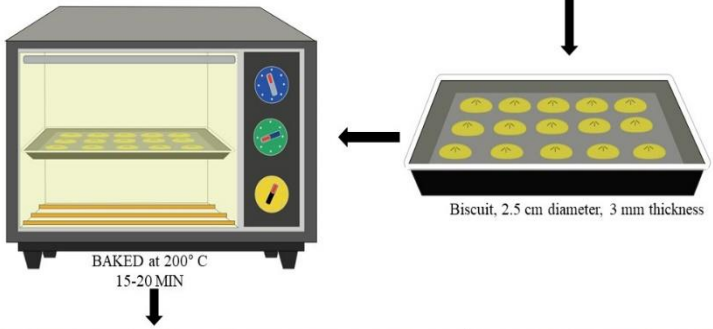
- Improves digestive function
- Reduces cholesterol levels
- Eases constipation
- Prevents diabetes, obesity and cardiovascular diseases

Bamboo Shoot Fortified Shoot products



Bamboo Shoot Cookies Preparation



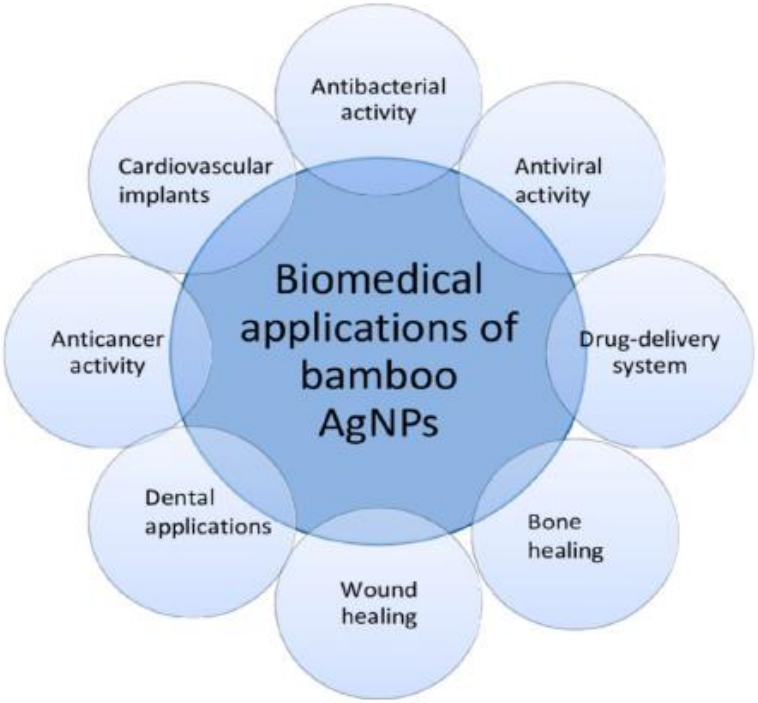


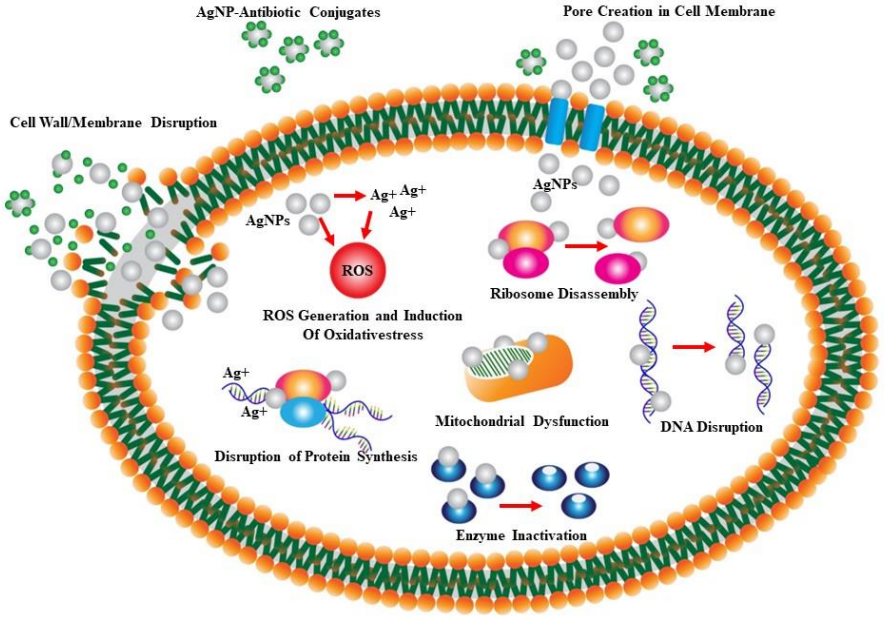
Nutritional Analysis of Bamboo Shoot Fortified Products

Free Amino Acids	4.22±0.07	0.08 ± 0.01 g/100g	0.51±0.01 g/100g	0.62±0.01 g/100g
Protein	3.50±0.01	1.15 ± 0.05 g/100g	0.63±0.01 g/100g	6.15±0.01 g/100g
Carbohydrate	3.29±0.01	14.66 ± 0.33 g/100g	16.26±0.22 g/100g	21.74±0.59 g/100g
Starch	1.11±0.01	59.47 ± 0.43 g/100g	75.32±0.08 g/100g	80.74±2.03 g/100g
Fat	1.17±0.05	27.27 ± 0.06 g/100g	26.36±0.29 g/100g	1.30±0.03 g/100g
Vitamin C	1.87±0.01 mg/100g	2.69 ± 0.13 mg/100g	2.13±0.03 mg/100g	1.41±0.02 mg/100g
Vitamin E	0.59±0.01 mg/100g	0.32 ± 0.01 mg/100g	0.33±0.01 mg/100g	0.48±0.07 mg/100g
Phenol	0.61± 0.01	0.14 ± 0.01 g/100g	0.15±0.01 g/100g	0.35±0.01 g/100g
Phytosterol	0.32±0.01	0.18 ± 0.01 g/100g	0.15±0.01 g/100g	0.08±0.01 g/100g
Crude Fiber	0.98±0.01	1.12±0.04 g/100g	1.16±0.01 g/100g	0.92±0.02 g/100g
NDF	5.50± 0.01	52.17±0.04 g/100g	71.05±0.02 g/100g	69.14±0.01 g/100g
ADF	1.65± 0.01	3.58 ± 0.01 g/100g	2.19±0.01 g/100g	1.51±0.01 g/100g
Potassium	5050.00±10.00	181.33±3.21 mg/100g	316.67±4.16 mg/100g	231.33±2.31 mg/100g
Phosphorus	590.67±3.06	80.00±6.56 mg/100g	144.00±4.00 mg/100g	128.67±1.15 mg/100g
Magnesium	227.33±3.06	30.00±5.51 mg/100g	46.00±5.29 mg/100g	48.67±1.15 mg/100g
Calcium	166.67±3.06	40.00±3.61 mg/100g	42.33±5.86 mg/100g	32.00±2.00 mg/100g
Silicon	187.33±3.05	28.67±4.16 mg/100g	22.00±2.00 mg/100g	9.40±0.35 mg/100g
Zinc	8.87±0.03	1.12±0.02 mg/100g	1.63±0.03 mg/100g	1.11±0.01 mg/100g
Iron	7.02±0.12	3.58±0.09 mg/100g	3.86±0.05 mg/100g	3.72±0.02 mg/100g
Manganese	6.76±0.05	3.35±0.06 mg/100g	0.83±0.03 mg/100g	0.73±0.03 mg/100g
Copper	2.79±0.03	0.85±0.05 mg/100g	0.93±0.03 mg/100g	0.63±0.03 mg/100g
Nickel	0.70±0.01	1.22±0.02 mg/100g	0.55±0.05 mg/100g	0.15±0.05 mg/100g
Antioxidant activity	943.11± 4.09	2012.13± 2.12 IC_{50} µg/ml	2387.92±19.13 IC_{50} µg/ml	1880.07±8.79 IC_{50} µg/ml
Food Calorie		308.62± 0.94 kcal/100g	304.82± 3.28 kcal/100g	123.28±2.65 kcal/100g

Bamboo Nanoparticles in Biomedical Applications

Because of their unique class of functional compounds, bamboo is an ideal candidate for the formulation of silver or gold nanoparticles.





Antibacterial activity of bamboo AgNPs

The Future in Food Technology…….

- Reduce contamination
- Food processing, food labeling and packaging
- Food transportation and service quality
- Increase food security and reduce environmental impact
- Improve crop yield and nutrition

Projects funded by

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Ministry of Food Processing Industries

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