

Bioprocess Engineering & Technologies in Reducing Waste and Creating Value

Sandeep B. Kale, PhD



QbD Purple Advanced Technologies Pvt. Ltd. (QPAT),
16, Sai Durga, Sahyadri Farms, Baner, Pune-411045, India
sandeep.kale@qpattech.com, qbdpurple@gmail.com; www.qpattech.com

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QPAT: Research and Scale up Portfolio

- Process Synthesis and Product isolation, Characterization
- Extraction, Separation and Purification of
 - Natural products & ingredients Herbal Products and API
 - Biotherapeutics – proteins, enzymes and antibodies, plasma proteins, hormones etc.
 - Fermentation
 - Synthetic intermediates and API
 - Metal ions
 - Sugar, Sugar Conversion and Water
 - Decolourization, detoxification, de-bittering and odd flavour removal
- Resin screening and process development
- Process optimization, integration, basic Engineering of pilot and commercial facility
- Lab demonstration *Scale Up and Commercialization*

1. Pharma API Purification
2. Natural Products, Nutraceuticals etc.
3. Food and Agroprocessing Waste Valorisation (secondary agriculture)
4. Fermentation (USP)
5. Process engineering, Key Equipments & Commercialization

Bioprocess Technology (commercial scale) = Biosciences + Engineering

Design, Development and Scale up of Processes and equipment's for the manufacturing of products such as agriculture, food, feed, biopharmaceuticals, nutraceuticals, biochemicals and biopolymers, paper etc. from biological material



Waste is a Resource



**Creating Health & Wealth from
Rejected Food and Agroprocessing
Resources**

Example of food wastes - worldwide



45%

FRUIT & VEGETABLES FOOD LOSSES

Along with roots and tubers, fruit and vegetables have the highest wastage rates of any food products; almost half of all the fruit and vegetables produced are wasted.



3.7 trillion apples



30%

CEREALS FOOD LOSSES

In industrialized countries, consumers throw away 286 million tonnes of cereal products.



763 billion boxes of pasta

32% of global food supply by weight

24% of global food supply by energy content (calories)

Losses at production are more prevalent in developing regions while food waste at consumption is more prevalent in developed regions

Majority of losses are during

- Fruits and vegetables
 - Agriculture and Processing
- Cereals
 - Post harvest, processing and distribution
- Oilseeds & pulses
 - Agriculture, post harvest and Processing



20%

OILSEEDS & PULSES FOOD LOSSES

Every year, 22% of the global production of oilseeds and pulses is lost or wasted.

Discarded Food - Valuable Unused Resources

Selected Grocery Items

Table 5. Farm to consumer waste hot spots for 5 selected grocery items.¹⁴³

Food waste type	Total Wasted (%)	Loss profile across supply chain (%)			
		Farming	Processing	Retail	Consumer
Grapes	24	6	<1	<1	16
Apples	41	11	2	<1	27
Bananas	20	2	7	1	10
Bagged salad	68	17	15	1	35
Bakery	48	5	14	4	25



Sze Ki Lin et al., Biofuels, Bioprod. Bioref. 8:686–715 (2014)

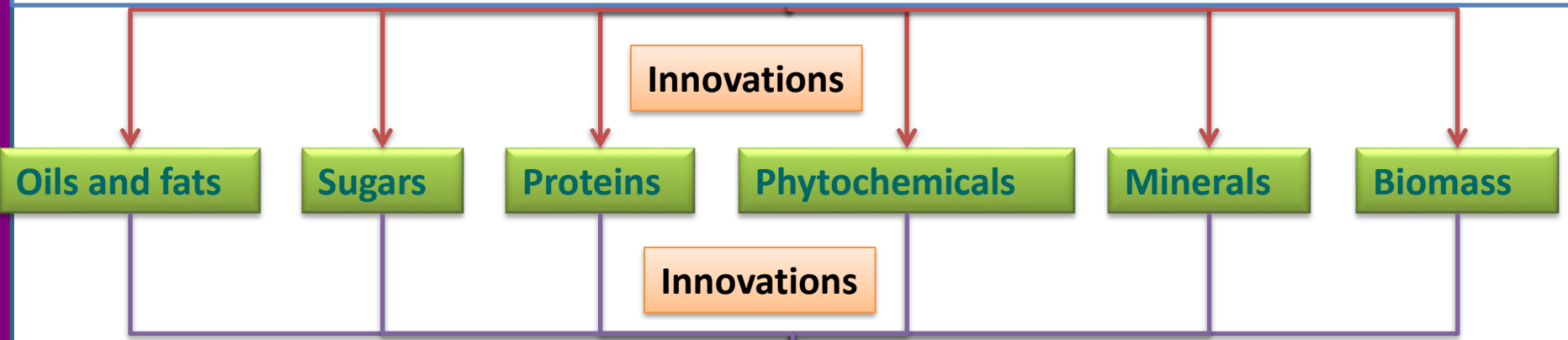
Bioprocessing of Food/Agro-processing Wastes



Wastes derived from processing of Primary Agricultural Produce



Efficient, Scalable and Viable Extraction, Separation and Purification platform Technologies



Efficient, Scalable and Viable Conversion Technologies

Value added Products (Secondary Agricultural Scenario)

Bioprocessing of Bioresources – Building Business Plan

*Skills and Product
Application Portfolio*

Efficiency

Key step

3. Business Model in Market (API, or Formulation)

- a) B2B, B2C; Contracts – traders, user industries etc.
- b) Credit period (revenue management, cash flow)
- c) Market potential
- d) Building new application

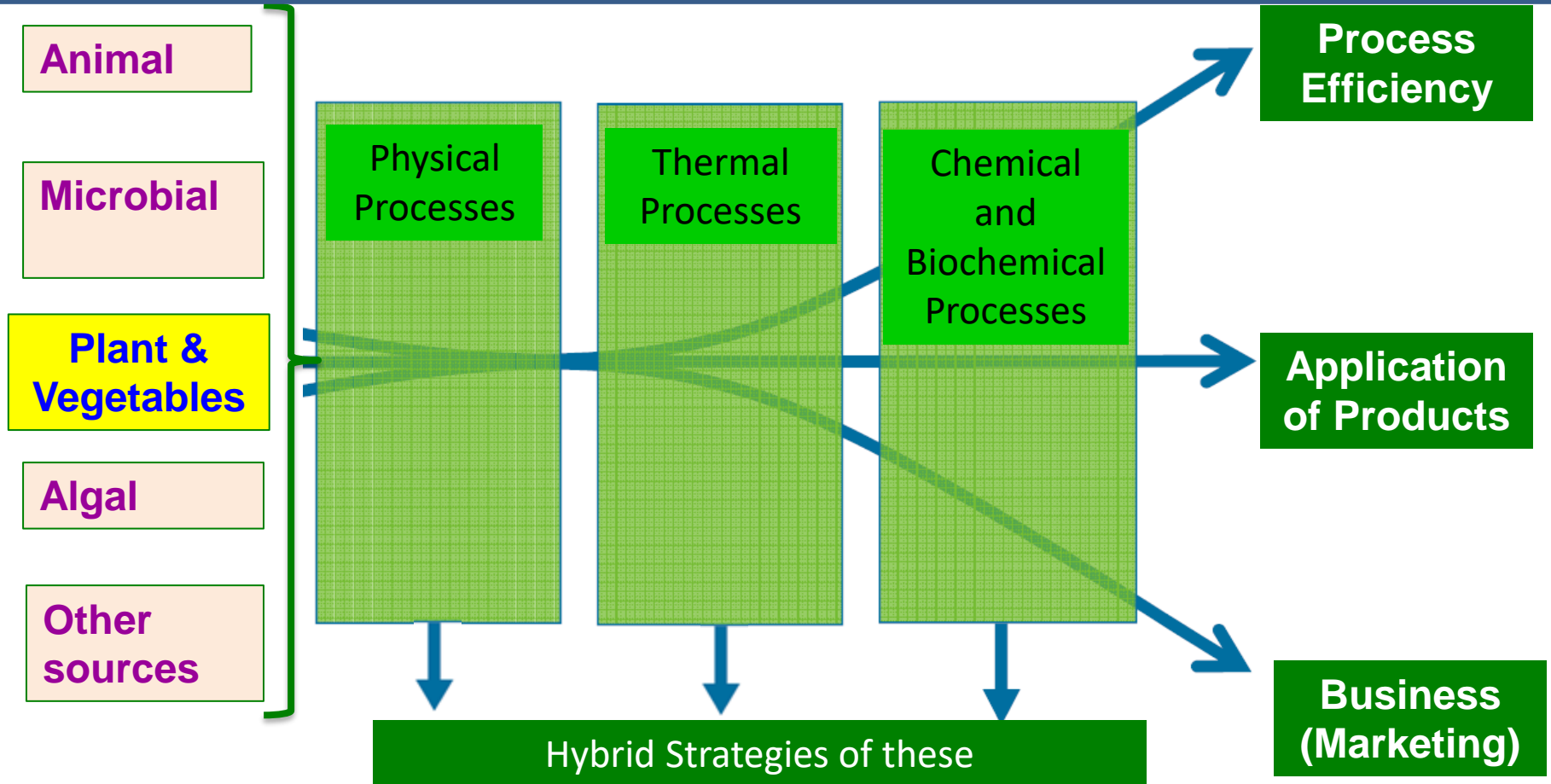
2. Processing Plant (for API or till formulation)

- a) Process Technology and Plant Engineering (multipurpose)
- b) Equipment and integration, piping
- c) Utilities (power, steam, water etc.)
- d) Effluent treatment (ZLD..?)
- e) QC/QA and others like maintenance etc.
- f) Working capital, OPEX, CAPEX
- g) Manpower (Skilled, unskilled)

1. Starting Resources

- a) Sourcing of raw materials & quantity
- b) Transportation of raw material.?
- c) Organized Vs unorganized availability
- d) Stability (immediate Vs delayed processing)
- e) Cost and payment terms

Food/Agroprocessing wastes



Small Molecules: Nutra, Health, Pharma, Cosmetics, Agro application
Gaseous Fuels: Bio-CNG;
liquid Fuels: Bioethanol, Biobutanol
Polymers (Cellulose, Pectin, Proteins): Food and Pharma applications
Inorganic: Silica, Minerals

'Efficient - Extraction, Isolation and Purification of products

1. Solid-Liquid Extraction

Supercritical fluid extraction

Pressurized liquid extraction

Microwave assisted extraction

Ultrasound assisted extraction

2. Liquid-Liquid Extraction

e.g. Centrifugal Extractors

Adsorptive chromatographic separations

Packed bed

Fluidized bed

Actual moving bed (FMB/LSCFB)

Simulated moving bed (SMB)

Flash Chromatography

Centrifugal chromatography

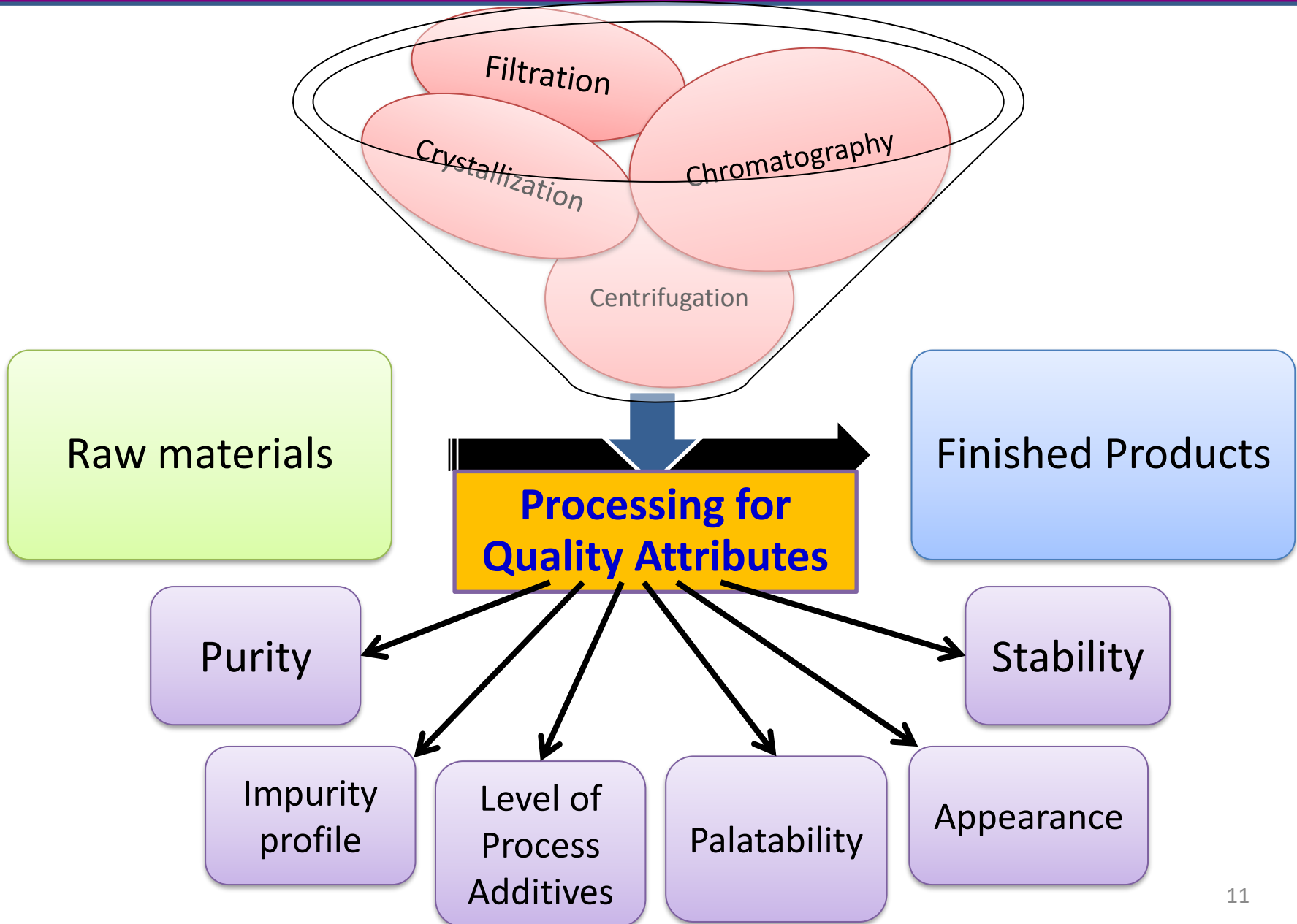
Membrane based separations

e.g. NF, UF, MF

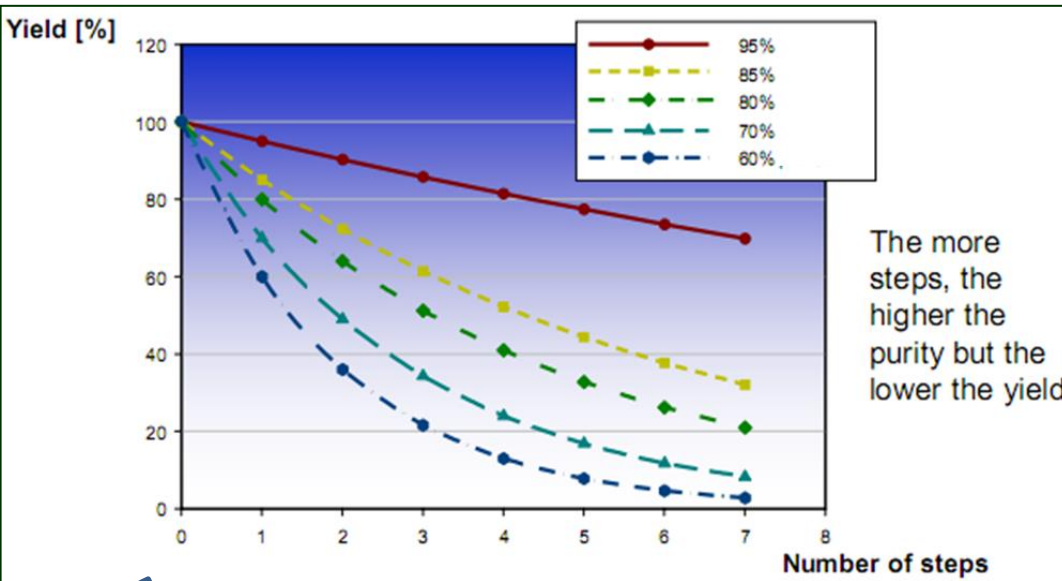
Other isolation & purification techniques (e.g. Crystallization, Distillation, filtration and drying)

Effectively Integrated isolation and purification techniques

Bioprocessing for Agrobased Products



How Do We Reduce Processing Cost And Increase Yields ?

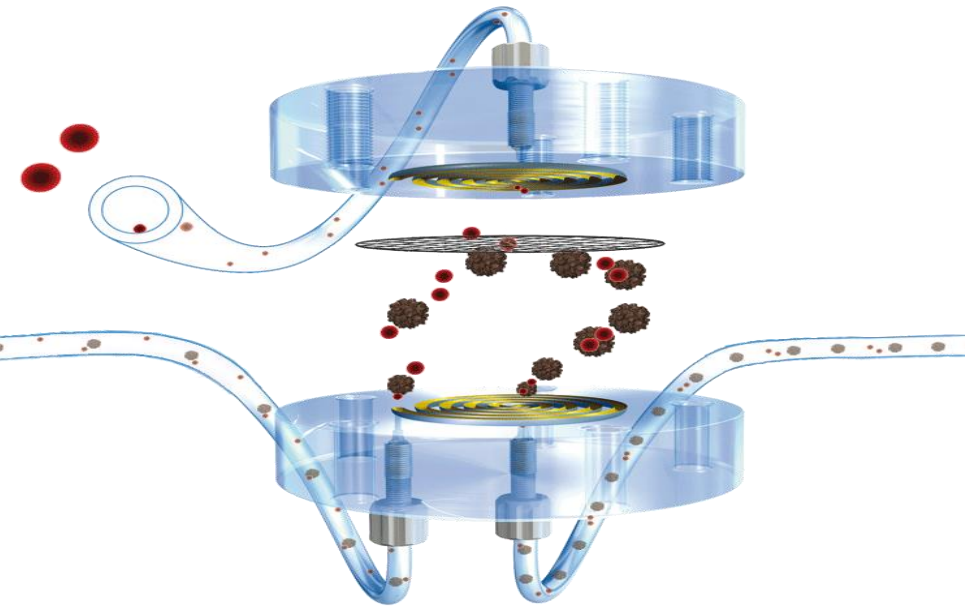


**Increase process efficiency
Reduce processing cost and
Reduce processing time !**

Two OPTIONS

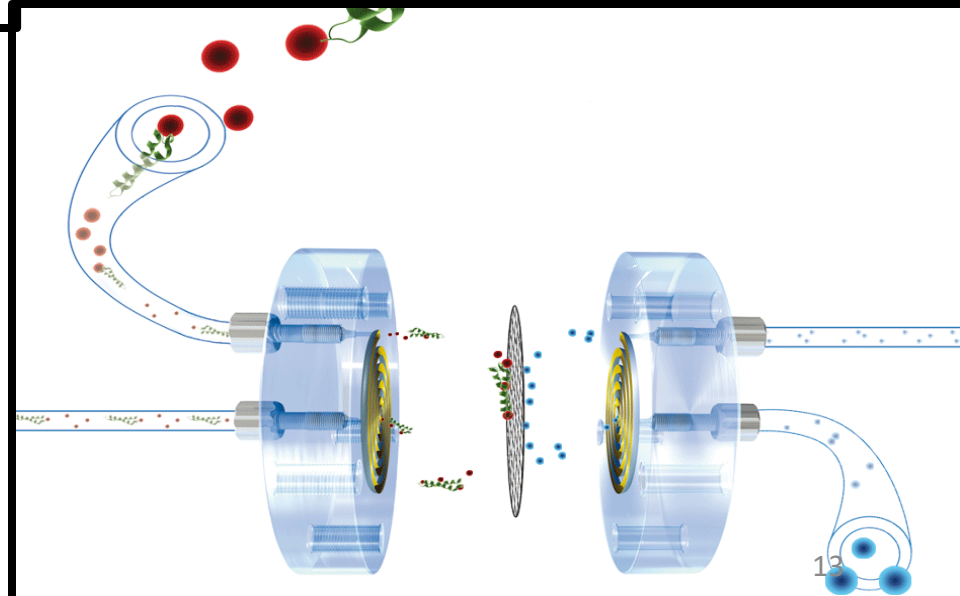
- Increase efficiencies of all steps**
- Reduce the number of steps**

Membrane Separation: TFF - UF, MF, NF



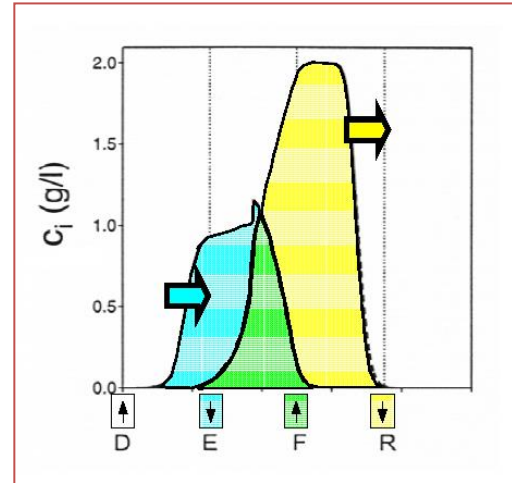
- Isolation biopolymers (proteins)
- Removal of proteins or polymeric mass from small bioproducts
- Desalting
- Concentration of biopolymers or small mol. Wt. bioproducts

- Recovery of enzymes during biotransformation, for recycle
- Integration with adsorptive separation

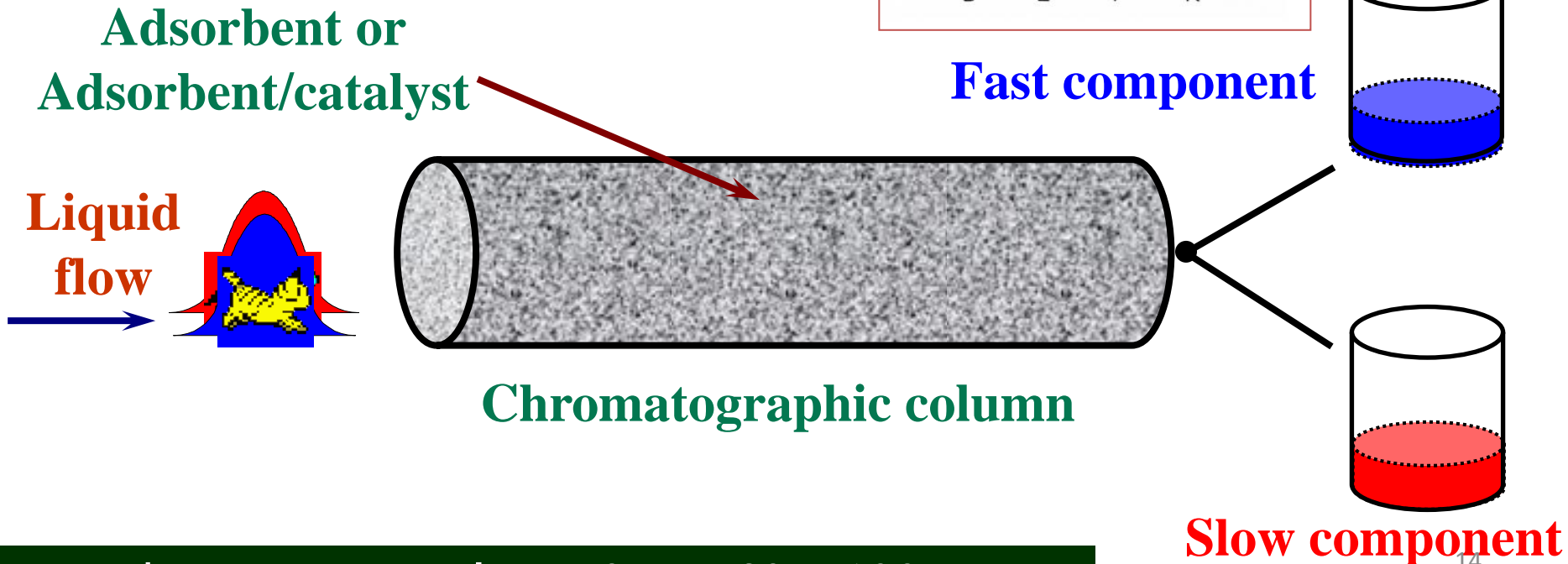


Separation and Purification Processes

- Separation is achieved by preferential adsorption of components in a chromatographic bed.
- Selective adsorption leads to different migration velocities



Isocratic
and/or
Gradient



Processing Plant Requirements

- 1) Raw Material (Input and Process chemicals - receiving bay, and raw material ware house)
- 2) Infrastructure in the plant area
 - a) Permissions (Pollution control board, manufacturing licence/s, solvent storage and usage permissions – if any)
 - b) Washing area and machine (or manual approach)
 - c) Crushing (if any)
 - d) Extractors - Solid-Liquid, Liquid-Liquid
 - e) Filtration & Purification equipment's (if any)
 - f) Drying equipment's (spray drying, tray drying, drum dryer etc)
 - g) Blenders, granulators etc.
 - h) Packaging units (bags, drums etc.)
 - i) Finished good warehouse
 - j) QC, QA and documentation
 - k) ETP – effluent treatment plant
 - l) Utilities (Boiler, chiller, cooling tower, power, water, vacuum etc.)
 - m) Manpower (skilled and unskilled) - HR

Bioprocessing of Agro-produce for Valorization

RM- I

- 1) TOMATO
- 2) POMOGRENATE
- 3) MANGO
- 4) CITRUS/ORANGE
- 5) GRAPES
- 6) SPINACH
- 7) Red cabbage
- 8) Capsicum
- 9) Carrot
- 10) Bacopa

RM - II

- 1) Peas
- 2) Soya Meal
- 3) Rice Bran (defatted)
- 4) Guar Meal
- 5) Moong
- 6) (Lentils/pulses etc.)

RM - III

- 1) Milk Whey

RM - IV

- 1) Sugar
- 2) Starch

Nutraceuticals
Heal Suppliments
Phytopharmaceuticals

Functional ingredients
Proteins & hydrolysates

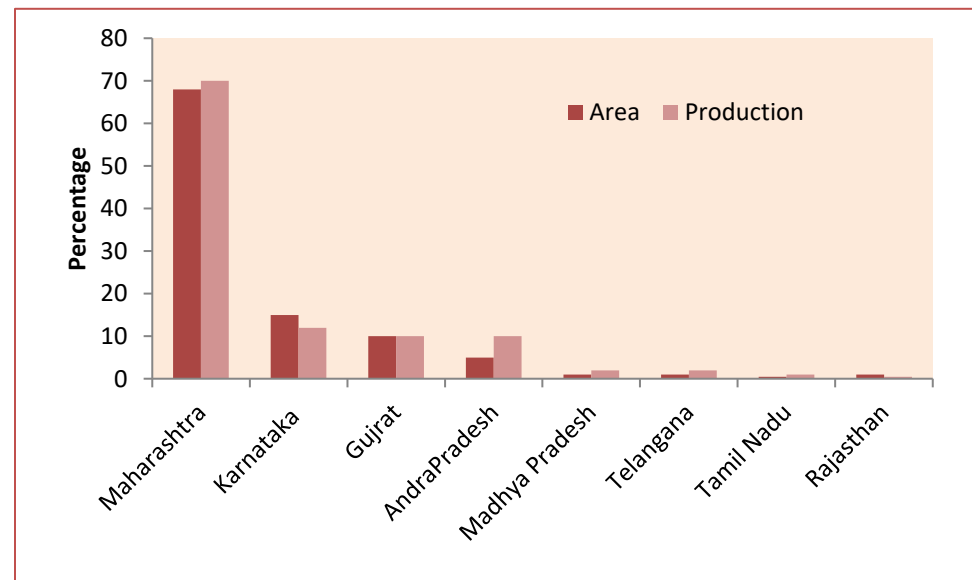
Sweeteners
Biopolymers
Modified sugars

Pomogrenate production in India

- **India ranks first** in pomegranate production (Productivity= 7.4 tonnes/ hectare) in the world.



- Maharashtra, **pomegranate basket of India** alone shows productivity of 6.7 tonnes/ hectare



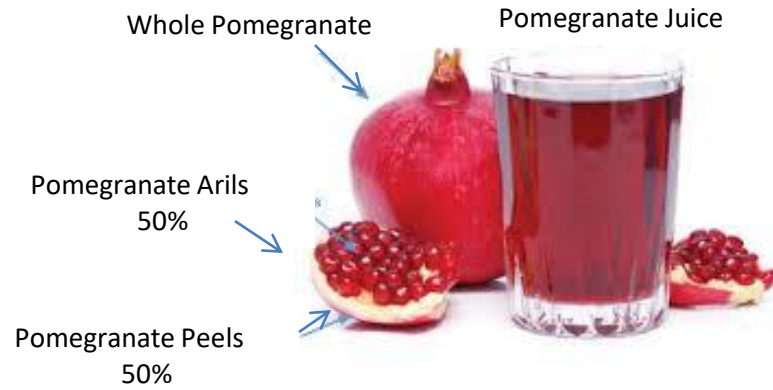
Value Addition:

- ✓ 50% peels from pomegranate juice processing Industry
- ✓ 20% post harvest losses- not suitable for export and domestic market

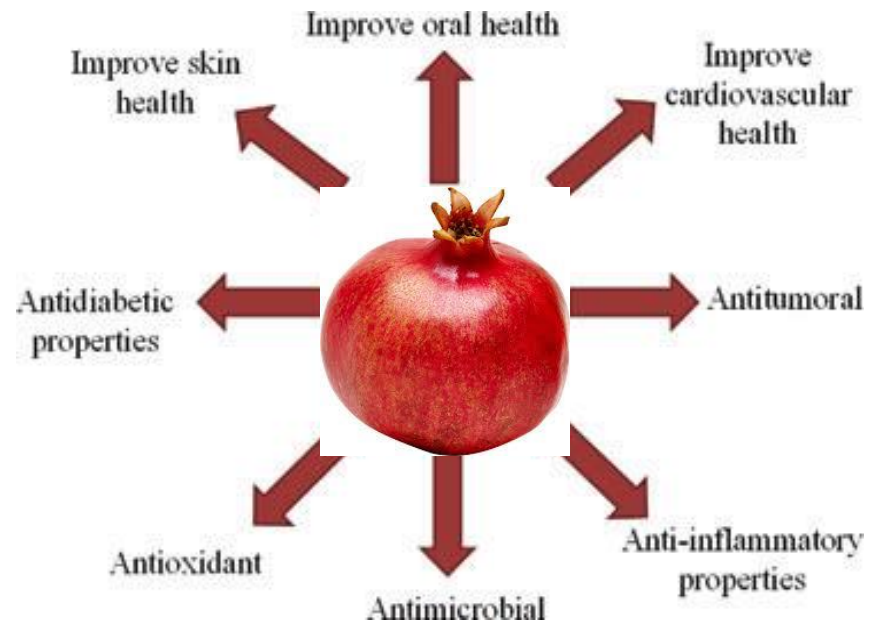
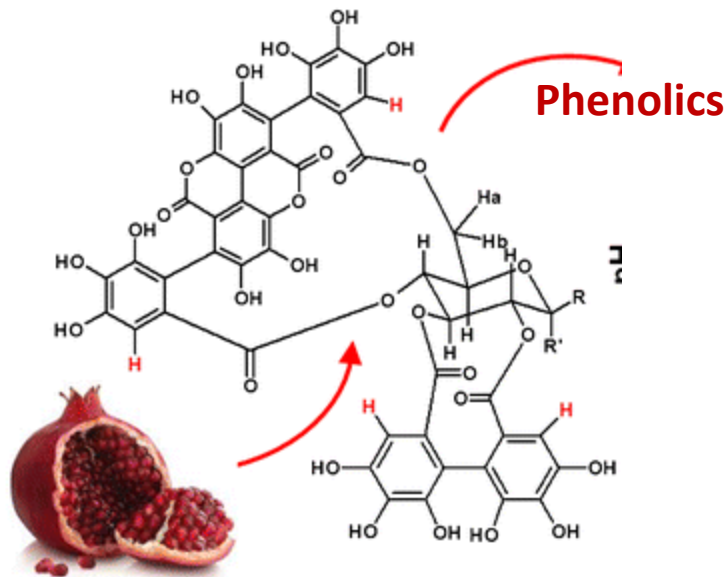
Pomogrenate



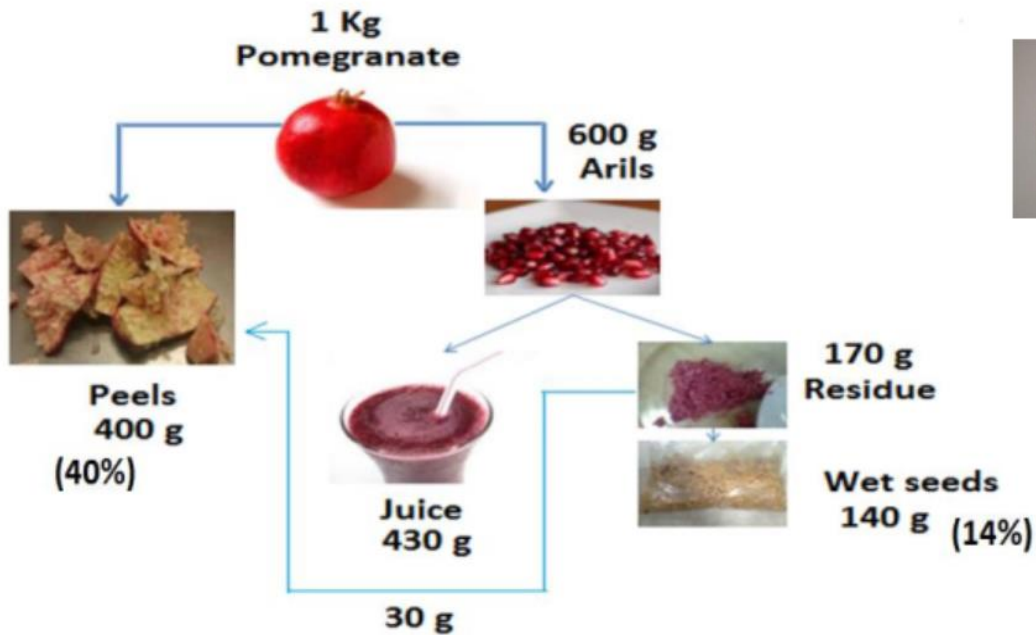
Punica gratum



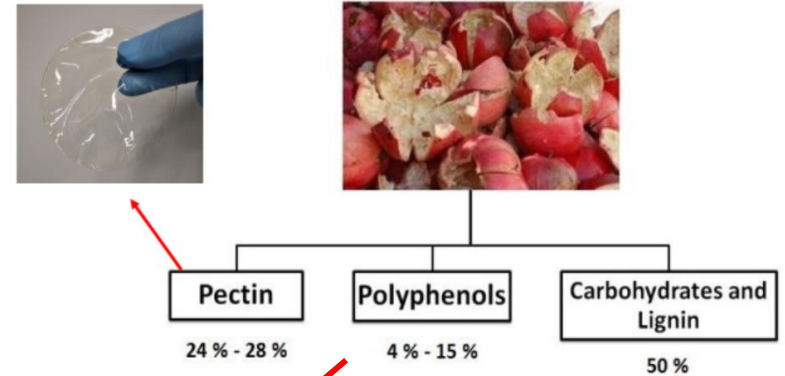
Composition of pomegranate peel powder



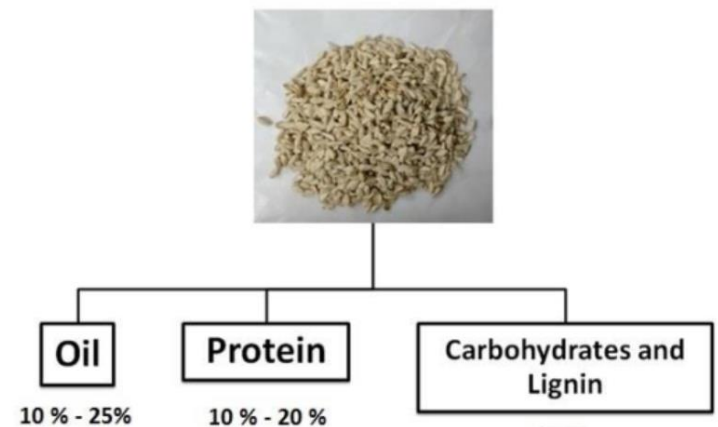
Pomegranate processing



Pomegranate peel

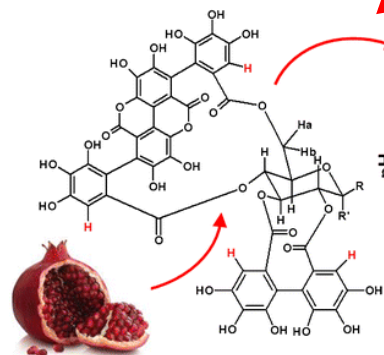


Pomegranate seeds



40-50% waste in the form of peels and seeds

Phenolics, antioxidants



Pomogrenate Waste Processing

Basis

- Total Pomogrenate (waste) : e.g. 10 tons/day
- Number of days of processing: 100 days

Sr. No.	Product recovered	Quantity per day (kg)	Total in a season 100 days (Tons)
1	Pomogrenate Extract (Type I)	400	40
2	Pomogrenate Extract (Type II)	800	80
3	Pomogrenate Extract (Type III)	320	32
4	Residue	3840	384
5	Total		536

Revenue: 1200 to 1500 Lakhs

Processing of Tomato Juice/Waste for Glutamate concentrate

Water
Carbohydrates - Major- Fructose, Glucose etc.
Organic acids - Citric acid, succinic acid etc.
Amino acids (Major: Glutamate and aspartic acid)
Protein
Fat(in seeds)
Minerals: Na, Ca, Mg, K, P, Fe & Mn
Carotenoids (as Lycopene)
Fiber
Vitamin C



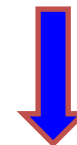
Red Ripe
Tomatoes

Chopping



Sieved
through 1/8''
Mesh

Juice/serum



Liquid output

Composition of starting material

Glutamate:	0.05 to 0.3%
Sugars:	4.5%
Organic acids:	0.9%
Amin acids:	0.1%
Proteins:	3.2%
Polysaccharides:	1.2%
Ash:	0.05%
Moisture/water:	89.8%

Apple Pomace



Selection and Cleaning

**59.21 million tonnes
per annum**

**75%
consumed
as fresh
fruit**



Ready to eat apples

Selection
Cleaning

25% processed



Apples for Juice

Squeezing , Pressing

Apple Juice



**Apple Pomace
3.7 Million Tons**

Incineration

Landfill

Composting

Animal Feed

Extraction of
Bioactives

Solid State
Fermentation

- ✓ Environmental Burden
- ✓ High BOD and COD
- ✓ GHG Emissions
- ✓ Decomposition (high moisture content)

- ✓ Value added products such as ursolic acid, vitamins, enzymes, antibiotics
- ✓ Pectin, Dietary fibers, Polyphenols, Carbohydrates, Bioactive molecules

The Idea

The selective adsorption technology separates potato proteins as potato protein isolate (PPI) and individual two classes of useful potato proteins Patatin (Pat) and Protease Inhibitors (PI)

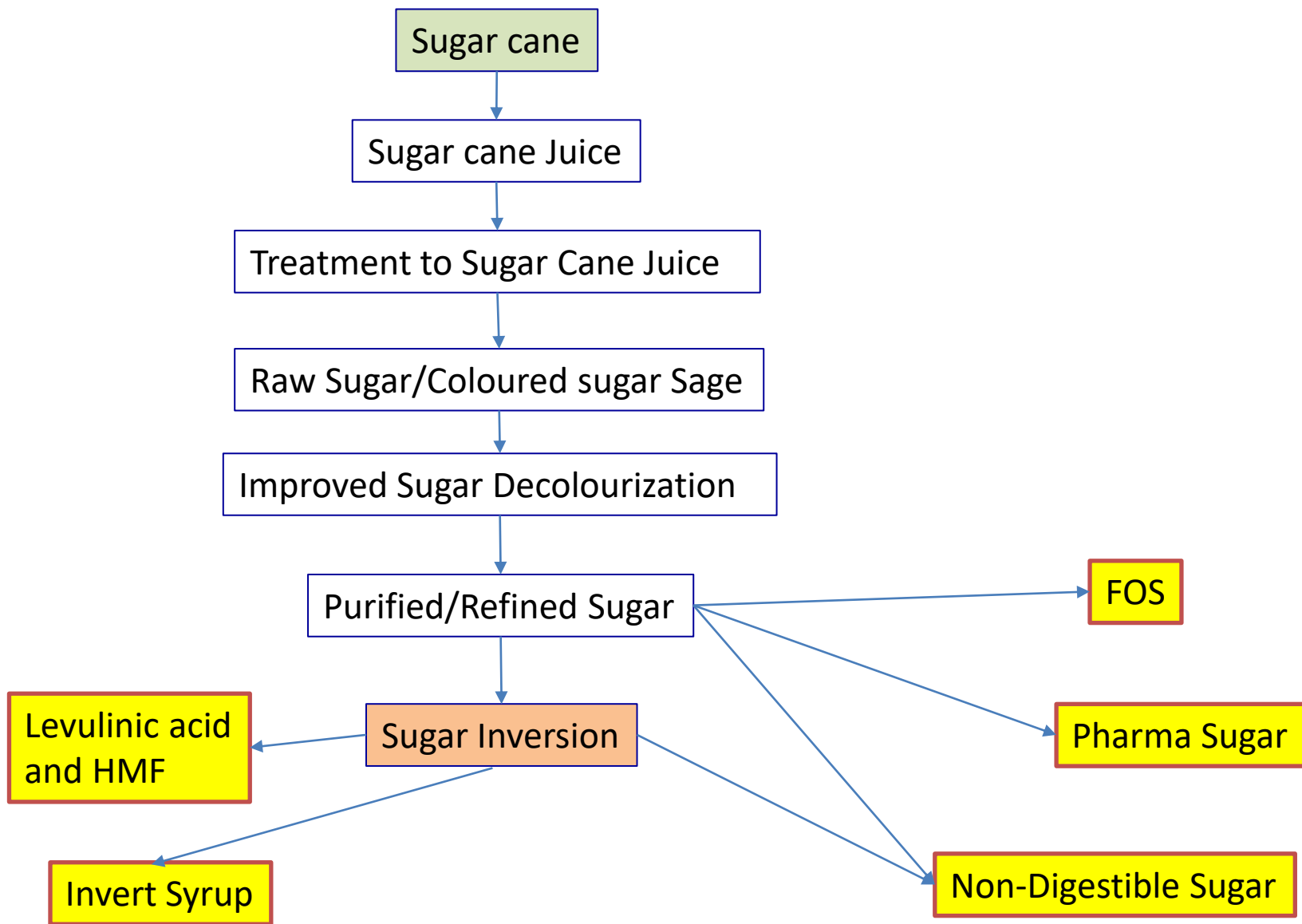
Technology simultaneously detoxifies the protein preparations by removing ANFs like glycoalkaloids (which are also recovered to make value added e.g. Solanidine)

The technology can be used to recover potato proteins (growing market), and starch and help to recycle the water from washing, blanching and other steps

Similar idea can be extended to pasta washings for starch and protein recovery (and water recycle)

Proteins from oilseeds, pulses, lentils and other agro-produce

Technologies for Sugar cane/Table sugar



Summary Points

- Raw material sourcing and availability
- Fruit and vegetable wastes are seasonal
- To produce multiple products and create biorefinery
- Better utilization of assets and early payback
- As a business case – decentralized processing plants
- Affordable products having value creation
- Quantity with supply chain

Contact:

Dr. Sandeep Kale

[Email: qbdpurple@gmail.com](mailto:qbdpurple@gmail.com)

Web: www.qpattech.com

Mobile: +91-9594351422

Thank You



**Bioprocessing technologies for
.....Health and Nutrition Mission**

**TAKE CARE OF
YOUR BODY.
IT'S THE ONLY
PLACE YOU HAVE
TO LIVE IN.**