The 3 A's of Section of Crop Utilization…

Achievements, Aspirations & Action Plan

भाकृअनुप-केन्द्रीय कन्द फसल अनुसंधान संस्थान

(भारतीय कृषि अनुसंधान परिषद)

श्रीकार्यम, तिरूवनन्तपुरम 695 017, केरल,भारत

ICAR-Central Tuber Crops Research Institute

(Indian Council of Agricultural Research)

SREEKARIYAM, THIRUVANANTHAPURAM 695 017, KERALA, INDIA

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Diamond Jubilee of ICAR-CTCRI

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From the Director

Dr. G. Byju

Tropical tuber crops stand as enduring symbols of resilience and sustenance providing nourishment, livelihoods, and cultural significance. Yet, due to their bulkiness and relatively short post-harvest lifespan, processing and value addition are essential aspects for maximizing their potential. Over the past six decades, ICAR-CTCRI has developed numerous value-added food products, industrial products, and machineries. Addressing the nutritional challenges inherent in tuber crops, the Section of Crop Utilization has focused on fortifying functional food products such as pasta, noodles, bakery items, and ready-to-eat products. Cassava starch, being a major industrial starch in India, technologies have been developed to make modified starches, composites, biodegradable films and disposable articles, as well as bioethanol from it.

The section's efforts extend to encompass the design and implementation of pre- and post-harvest machinery, including harvesting tools, peeling machines, and starch extraction plants. The Indian patent awarded for the power operated Chinese potato grader stands as a notable recent achievement of the section. Furthermore, the techno-incubation centre at headquarters and regional station are involved in promoting entrepreneurship in value added products among the stakeholders.

This book serves as a comprehensive compendium of the Section of Crop Utilization's significant achievements, future aspirations, and strategic action plans. It is intended to serve as a valuable resource for stakeholders seeking to strengthen the tuber crops sector in India, offering insights, inspiration, and a roadmap for sustainable progress.

G. Byju
Director

01 July 2024

Our Mission

- To develop and refine post-harvest storage and processing techniques for minimization of losses in tropical tuber crops.
- To develop value added food products and industrial products from tuber crops and its byproducts.
- To develop and refine pre- and post-harvest machinery for tuber crops.
- Basic studies on the biochemical/phytochemical composition, bioactivities and starch properties of tuber crops.

Our Team

Scientists: 4

Sl.No.	Name	Cadre Discipline
1.	Dr. A. N. Jyothi, Principal Scientist & SIC	Agricultural Chemicals
2.	Dr. M. S. Sajeev, Principal Scientist	Agricultural Structure & Process Engineering
3.	Dr. T. Krishnakumar, Scientist	Agricultural Structure & Process Engineering
4.	Dr. Pradeepika Chintha, Scientist	Vegetable Science

Technical (1) & SSS (1)

1.	Mrs. R. Nijamol	Technician
2.	Mr. N. Shiju	Skilled Support Staff

Ph.D. Scholar: 1
Junior Research Fellow: 1
Young Professionals: 3
Skilled Contractual Staff: 3

What have we delivered?

1. Value added food products

Process for the production of value added food products and functional foods from various tuber crops, which include snack foods, bakery products, pasta, noodles, instant food mixes, nutribar, vacuum fried chips and rice analogues.

2. Products for industrial sector

Process for the production of physical and chemical modified starches, resistant starches, minimally processed tuber crops, functional sago, starch-graft-copolymers, composites & nanocomposites for food and pharmaceutical applications, adhesives, superabsorbent polymers, thermoplastic starch sheets, biofilms, particles boards, biodegradable disposable articles, sweet potato wine, bioethanol and wax coating technology for cassava.

3. Pre- and post-harvest machineries: Cassava harvester, peeler, chipping machines, raspers, mobile starch extraction unit, feed granulator, Chinese potato grader.

4. Technologies for animal feed sector: Ensiling technology for cattle feed, cassava leaf concentrate based fish feed and granulated poultry feed.

5. Basic knowledge on biochemical constituents and bioactivity of tropical tuber crops: Established the biochemical profiles of tuber crops, their bioactivities, processes for the elimination of anti-nutritional factors, starch isolation and characterization techniques

1. Value added and Functional Food Products

Section of Crop Utilization has developed technologies for a range of value added food products as listed below.

- **Fried/snack food products** include cassava/tapioca pakkavada, sweet fries, sweet/salty demons, nutrichips (with/without egg), crisps, hot sticks and murukku.
- **Intermediary food products** namely Yuca Rava and Yuca Porridge from cassava flour.

- **Functional Foods**
  - Noodles and pasta enriched with protein, fibre and antioxidants. These include gluten free spaghetti, pasta and noodles from fortified sweet potato and cassava flour enriched with different protein sources, natural pigments, and dietary fibre.
  - Sweet potato based nutribar enriched with protein.

Snack foods

Fortified pasta, noodles and nutribar

- **Ready-to-eat extruded products** from tuber based composite flours fortified with corn flour, wheat, finger millet flour, soy flour, sweet potato-banana, fermented cassava-rice-wheat, orange fleshed sweet potato-spice blend, elephant foot yam flour and arrowroot with high nutritional and market value.
- **Bakery products** protein and fiber enriched cookies from orange and purple fleshed sweet potato rich in biofunctional components, gluten free cookies from taro, rusk from cassava flour,

cassava-millet cookies, protein enriched sweet potato muffins, beta-carotene rich and anthocyanin rich sweet potato cakes.

- **Vacuum fried chips** from orange fleshed and purple fleshed sweet potatoes with high carotene and anthocyanin content, respectively. These chips are lower in fat content and higher in bioactive compounds (beta carotene - 6.81 mg $100g^{-1}$ & anthocyanin - 57.44 mg $100g^{-1}$).

Extruded and bakery products

- **Food Mixes**
  - Weaning food mixes, ready-to-use paratha mix from sweet potato flour, ready-to-use sweet potato laddu mix are the major food mixes developed from tubers crops.
  - Anthocyanin and carotene enriched nutrijelly, sweet potato based sauces, jams, pickles and wine were developed.

Food mixes, nutrijelly and pickles

- **Ready-to-fry products** include papads, nutri-shreds and pop-ups.

Ready-to-fry products

- **Rice analogues** were developed from cassava and sweet potato based composite flours by cold extrusion process.

Rice analogues

2. Industrial Products and Processes

Industrial products and processes for food sector

- **HQCF**: Process for the production of high-quality cassava flour by (HQCF) static pressing method.
- **Quick cooking dehydrated tubers**: Dehydrated cassava tubers (2-3 min) and elephant foot yam tubers (5-6 min) of comparable texture as that of the fresh cooked tubers.

High quality cassava flour

Quick cooking tubers

- **Functional sago**: Sago from reconstituted cassava dry starch and functional sago from wet and reconstituted cassava dry starch fortified with natural pigments.

Sago from reconstituted starch Functional sago enriched with natural pigments

- **Wax coating technology for enhancing the shelf life of fresh cassava tubers**: Coating of the roots with paraffin wax, along with a fungicide prevents rapid onset of PPD and extends shelf-life to about one/two months longer.

Wax coating of cassava tubers

- **Food grade modified starches of cassava**: These can be used as thickening agent, gelling agent, binding agent or emulsifying agent in different food products.

1. Cassava starch succinate
2. Octenyl succinate cassava starch
3. Hydroxypropylated cassava starch
4. Crosslinked cassava starch

5. Cassava monostarch phosphate
6. Cassava distarch phosphate
7. Cassava starch citrate
8. Annealed cassava starch
9. Heat-moisture treated cassava starch
10. Pregelatinized cassava starch

Pregelatinized cassava starch

Cassava starch phosphate and its use in edible jelly

Food grade modified starches of cassava

- **Resistant starch (RS):** RS mimics dietary fibre in physiological action, associates with low calories, helps the growth of essential colon micro-biota and hence good for colon health. RS3, RS4 and RS5 type resistant starch enriched modified starches were developed from cassava and sweet potato.
  - RS3 type cassava and sweet potato starches with glycaemic index in the range of 54 to 57 were developed by retrogradation process.

RS4 type cassava resistant starch

RS5 type cassava resistant starch

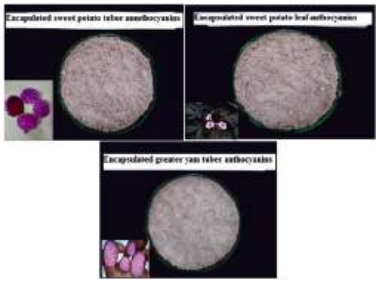
- RS4 type cassava and sweet potato starch with medium glyceamic index (58-60) were developed by chemical modification technique.
- RS5 (starch-lipid complex) type resistant starches of cassava and sweet potato with medium glyceamic index (55-63) were made by complexation with lipids.

- **Cassava starch based nanocomposite films for food wrapping application**
  - Cassava starch-konjac glucomannan blends for liquid coating of fruits and vegetables to enhance the barrier properties and shelf life.
  - Starch based biodegradable films for food wrapping applications.

Coated carrot slices

Cassava starch based wrapping film

- Sweet potato and purple yam anthocyanins were encapsulated with maltodextrin by spray drying to prepare natural colorant with the added advantage of antioxidant properties. Anthocyanin supplement was also developed in the form of capsules.



Colour concentrate and spray dried anthocyanin pigment from sweet potato and purple yam

Anthocyanin capsules

Industrial products for non-food sector

- **Cassava starch factory effluent treatment plant:** An integrated effluent treatment system has been developed for management of toxicity, BOD and COD in the waste waters generated from cassava starch/sago industries.
- **Commodity chemicals**: Processes have been developed for the production of commodity chemicals such as ethanol, citric acid and monosodium glutamate from cassava starch and residues. A conventional process for cassava bioethanol production was patented in 1983. An improved bench scale process involving specialty enzymes was also developed for ethanol production.

Cassava bioethanol

- **Cassava starch based biodegradable plastics and films**: A technology has been patented for producing ecofriendly biodegradable plastics from cassava starch.

Biodegradable plastics

- **Biodegradable films** were developed from native and modified cassava starches in combination with waxes viz., paraffin wax, microcrystalline wax, bees wax, candelila wax, carnauba wax and rice bran wax; proteins (whey protein concentrate and casein); modified starches and nano clays and different spice oils

- **Thermoplastic starch (TPS)** are alternative materials for petroleum-based materials for single-use packaging material applications. Thermoplastic starch sheets were made from native and modified cassava starch reinforced with fibre sources (saw dust, rice straw, rice husk, bagasse, banana fibre) and cassava stem/coconut pith-glycerol blends.

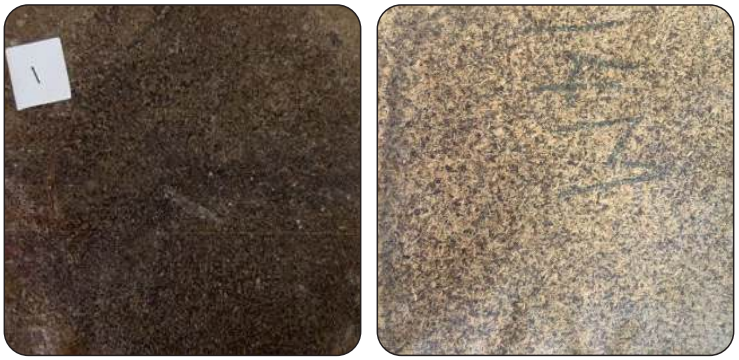
Thermoplastic starch sheets

- **Cassava starch based eco-friendly disposable articles** are being made by injection moulding with modified cassava starch/poly lactic acid blends.
- **Cassava starch based adhesives**

Simple low-cost technologies have been developed to prepare gums with and without chemical additives.

- Binding paste
- Special purpose adhesives
- Liquid adhesive from cassava starch
- Corrugating adhesives: Alkali free and moisture resistant corrugating adhesive formulations

- **Particle boards from crop residues**
  - Particle boards are being developed from dried cassava stem and synthetic resins, 'Green' particle boards using native/modified cassava starch as binder, and cassava stem-sugar cane bagasse composites.



Particle boards from cassava stem

- **Modified cassava starches**
  - Modified starches of cassava include oxidized starch, acid thinned starch, crosslinked starch, starch phosphate, starch phosphate carbamate, starch esters for textile, paper, adhesive and water treatment applications.
- **Grafted starches and superabsorbent polymer (SAP) based on cassava starch**
  - The semisynthetic SAP developed from cassava starch with a water absorbency of 300-400 gg^{-1} can be used as soil additive for moisture retention.
  - Process for production of graft copolymers of cassava starch suitable for use in textile sizing and flocculant in water treatment.
  - Lab scale process for urea fertilizer coated with cassava starch-graft-copolymer for extended release of nitrogen in the soil.

Superabsorbent polymer

Grafted cassava starch as flocculant

Coated urea

Cassava starch phosphate carbamate

3. Pre- and Post-harvest Machineries

Several machineries suitable for small holdings and primary processing of tuber crops have been developed to facilitate marketing and utilization of cassava and to avoid heavy post-harvest losses. These include:

1. Cassava harvesting tools (1st order and 2nd order lever types)
2. Hand Peeling device/knife
3. Continuous type cassava peeler for small scale processing
4. Dryers (Electrical and non-conventional energy based)
5. Cassava chipping machines: Hand operated, pedal operated and motorised chipping machines (capacity 120-1000 kg h^{-1}).
6. Cassava raspers: for the extraction of starch (capacity 900-1000 kg h^{-1}); Industrial cassava rasper (2 t/h) capacity
7. Mobile starch extraction plant: Capacity 200-500 kg h^{-1}
8. Portable self-propelled tapioca stem cutter for high quality tapioca setts production: Hand or pedal operated with rotary cutting blade. The cutting efficiency, percentage of damaged setts and output capacity were 98%, 0.45% and 3600 setts per hour, respectively.
10. Mobile Starch Extraction Plant: Capacity 200-500 kg h^{-1}
11. Centrifugal granulator for cassava based feed: Output 20 kg h^{-1}
12 Hydrocyclone system for cassava starch milk concentration
13. Pilot plant for liquid adhesive from cassava starch: Output 100 litre
14. Prototype continuous steaming machine for sago wafers/sago papad production
15. Power operated size based Chinese Potato Grader: Capacity 1000 kg h^{-1}
16. Arrowroot starch extraction machine

Cassava harvester

Chipping machines

Raspers

Cassava stem cutter

Mobile starch extraction plant

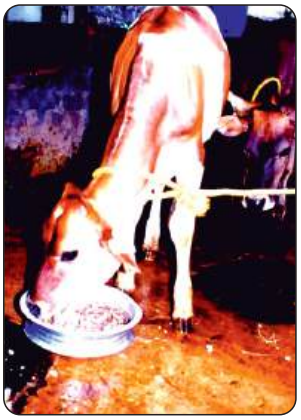
Feed granulator

Chinese potato grader

Cassava peeling machine

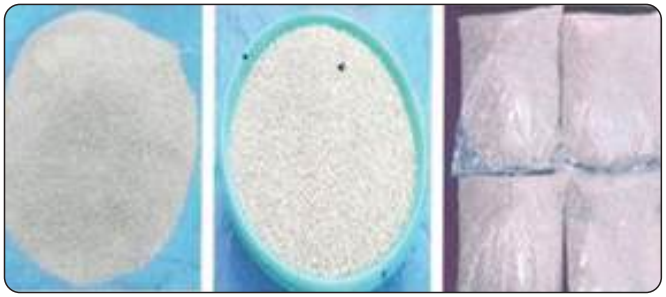
4. Technologies for Animal Feed Sector

- **Cassava Ensiling Technology** Technology for ensiling cassava have been developed to realize the potential of this crop as animal feed. The technology has also been scaled up in plastic silos (200 kg capacity) and underground silos to find its feasibility as a storage technique.

Cassava silage as cattle feed

- **Cassava based poultry feed** extrudates with Bengal gram, de-oiled groundnut cake and coconut cake.



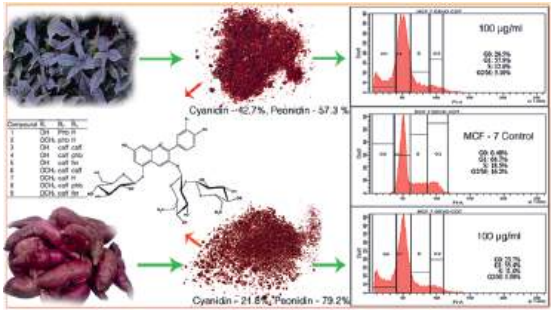

Poultry feed

- **Fish feed** was developed from cassava leaf protein concentrate.

5. Basic Research: Biochemistry

The section has carried out extensive studies on the biochemical composition, bioactivities, nutritional and antinutritional factors present in the crops and processing methods to eliminate the antinutritional components.

- Identification and quantification of nutritionally important biochemical constituents in various tuber crops: Protein, Flavonoids, Carotenes, Phenolic compounds, Mucilages, Vitamins and Minerals.
- Studies on the effect of different processing techniques on the retention of carotenoids and anthocyanins in tubers.
- Identification, quantification and functional studies of antinutrient factors in different tuber crops
  - Cyanoglucosides in cassava
  - Enzyme inhibitors in sweet potato
  - Calcium Oxalate in Aroids
  - Diosgenin in Yams
- Techniques for the elimination of antinutrient factors in tuber crops through different processing techniques.
- Identification and structure elucidation of anthocyanins in the tubers and leaves of purple sweet potato and purple yams.
- Antiproliferative and antioxidant effects of tuber anthocyanins by cell line studies with human cancer cells.
- *In silico* molecular docking studies to establish the quantitative structure-activity relationship of tuber anthocyanins, the type of interactions and the amino acid residues involved in it.



6. Other Information

External funded Projects

No. of external funded projects completed	:	16
No. of external funded projects (ongoing)	:	2
No. of contract research projects (ongoing)	:	3

Student Guidance

Ph.D. Guideship for faculties	:	Biochemistry, Chemistry, Biotechnology (University of Kerala)
No. of Ph.Ds. produced	:	20
No. of Ph.D. ongoing	:	1

Trainings and entrepreneurship development in value addition

Activities at Techno Incubation Centre [funded by Small Farmers Agri Business Consortium (SFAC), Govt. of Kerala]

Total trainings conducted (from 2013)	:	213
Participants	:	6000 (Male : 2343 and .Females : 3657)
Number of incubatees	:	162

Techno Incubation Centre at HQ

Facilities and Infrastructure

The Section has different laboratories equipped with instruments for the proximate analysis and biochemical analyses of plant samples, chemical reactions for starch modification and a starch characterization laboratory. The section has a workshop and a Techno Incubation centre with facilities for conducting hands-on training on entrepreneurship and value addition in tuber crops. The major equipment in different laboratories are listed below.

Chemical and Food analysis Laboratories

- HPLC
- Lyophilizer
- Rotary Flash Evaporator
- FT-NIR
- HP-TLC
- UV-Vis Spectrophotometer
- Homogenizer
- Cooling centrifuge
- Incubator
- Coating Machine
- Stability Chamber
- Tissue lyser
- Deep Freezer, -20 degree Celsius
- Colourimeter

Starch Characterization Laboratory

- Rapid Visco Analyzer
- Brookfield Viscometer

- Microwave Synthesiser
- Mill

Techno Incubation Centre

- Chipping machine-manual/mechanical type
- Electrical dryer
- Flour mill (hammer type)
- Dry blender (horizontal ribbon type)
- Kneading machine
- Pasta making machine: table top and stand-alone types
- Twin screw extruder
- Floor type sheet making and diamond shape
- Two burner range (industrial type)
- Packaging Machine: hand and pedal operated, band type and automatic filling
- Seva making machine

Workshop

- Drilling machine
- Welding machine
- Hydraulic press
- Band saw
- Bending machines
- Plate making machine
- Hydraulic press plate making machine

Awards and Recognition

Sl. No.	Item	Year
1	Hari Om Trust award	1993
2	Young Scientist award by Deseeya Sasthra Vedi	1996
3	ICAR Outstanding Interdisciplinary Team Research Award	1998 and 2014
4	NRDC Reward for Biodegradable plastics	2000
5	Norman E. Borlaug Fellowship, Cornel University, USA	2008
6	Dr. G. Rangaswami Memorial Young Scientist Award	2011
7	International Training Fellowship by NAIP, Iowa State University, USA	2011
8	Young Scientist Award, KSCSTE	2011
9	Young scientist award from Genesis Urban and Rural development (GUARD) Society, Hyderabad	2016
10	Young Researcher Award by Institute of Scholars (InSc), Bengaluru	2020
11	Best oral presentation awards	2007, 2009, 2016, 2020
12	Netaji Subhas-ICAR International Fellowship for Ph.D. progammme, North Dakota State University, USA	2017-2021
13	Achievement Award by Society of Tropical Agriculture	2021

Technologies Commercialized

Sl. No.	Name of technology	Amount (₹ lakhs)	No. of licenses issued	Total amount (₹ lakhs)
1	Chipping machine	0.80	2	1.60
2	Lever type cassava harvester	0.05	1	0.05
3	Mobile starch extraction plant	0.10	1	0.10
4	Electronic Gadget for measuring starch content of cassava tubers	0.10	1	0.10
5	Cassava starch based superabsorbent polymer	5.00	1	5.00
6	Wax coating of cassava tubers	0.25	2	0.50
7	Chinese potato grader	0.25	1	0.25
8	Arrowroot starch extractor	0.10	1	0.10

9	Cassava based protein enriched noodles	0.50	1	0.50
10	Fried snack foods and fried chips from tapioca	0.25	29	0.725
11	Quick cooking dehydrated cassava tubers	0.25	4	1.00
12	Protein enriched pasta and noodles	0.50	3	1.5

The technologies of Sweet potato vacuum-fried chips and Sweet potato nutribar were selected for branding by Kerala Startup Mission.

Patents

Indian patents were awarded to the following technologies

- Starch based biodegradable plastics (four patents)
- Process for producing cassava alcohol
- A mobile starch extraction unit
- Process and plant for producing decontaminated water from industrial effluents of cassava starch factories
- A low cost biotechnique to extract starchy flour with modified functional attributes from cassava.
- A power operated size-based Chinese potato (koorka) grader and a method of grading thereof.

Technology certification by ICAR, New Delhi

The following three technologies were certified by ICAR, New Delhi in 2023 and 2024.

1. Power operated size based Chinese potato grader (Lead Developer: T. Krishnakumar; Associate Developers: M.S. Sajeev, C. Pradeepika, R. Muthuraj and D. Jaganathan) (2023)
2. Wax coating for fresh cassava tubers: Improving preservation and enhanced shelf-life (Lead Developer: Saravanan Raju; Associate Developer: T. Krishnakumar (2023)
3. Cassava and Sweet potato Resistant Starch - RS4 type (Chemically modified) (Lead Developer: A. N. Jyothi; Associate Developers: R. Remya and J. Sreekumar) (2024)

Contract Research Projects

Sl. No.	Tile of the Project	Cost (₹)	Funding agency
1	Production of low-moist gelatinized dough for using in cassava (tapioca) papad making machine (Completed)	1,09,500	M/s Boosters International, Aravaimozhi, Kanyakumari, Tamil Nadu
2	Integration of sweet potato production and processing in Belgaum on a consultancy mode (Completed)	9,52,600	M/s Belgaum Minerals, Belgaum
3	R&D and commercialization of Process for High Quality Cassava Flour (HQCF) and continuous wet cassava pressing machine for production of HQCF (Completed)	3,00,000	M/s Verds Fab Products, Arumbakkam, Chennai
4	Jackfruit – Cassava Gluten Free Pasta (Completed)	40,000	M/s Artocarpus Foods Pvt. Ltd., Kinfra Park, Kannur, Kerala
5	R&D of process for the Cassava-jack fruit bulb flour-based pasta (Completed)	78,376	Smt. Rajasree, R., Nooranad, Alapuzha, Kerala
6	Development of pasta & cookies from "Sprotone" added with tuber starches as binding agents (Completed)	1,76,646	M/s Moza Organic Private Limited, Ernakulam, Kochi, Kerala
7	Developing the Standard Operating Procedures (SOP) for good manufacturing practices and Hazard Analysis and Critical Control Points (HACCP) for tapioca starch and sago production (Ongoing)	31,11,490	M/s SAGOSERVE, Salem, Tamil Nadu
8	Development of Cassava Custard (Ongoing)	8,42,000	M/s KCM Agri Clinic, Tirunelveli, Tamil Nadu
9	Development of value-added products from Mudali (*Colocasia esculenta*) and Kone (*Dioscorea*) (Ongoing)	6,48,174	M/s Spudnik Foods, Bengaluru, Karnataka

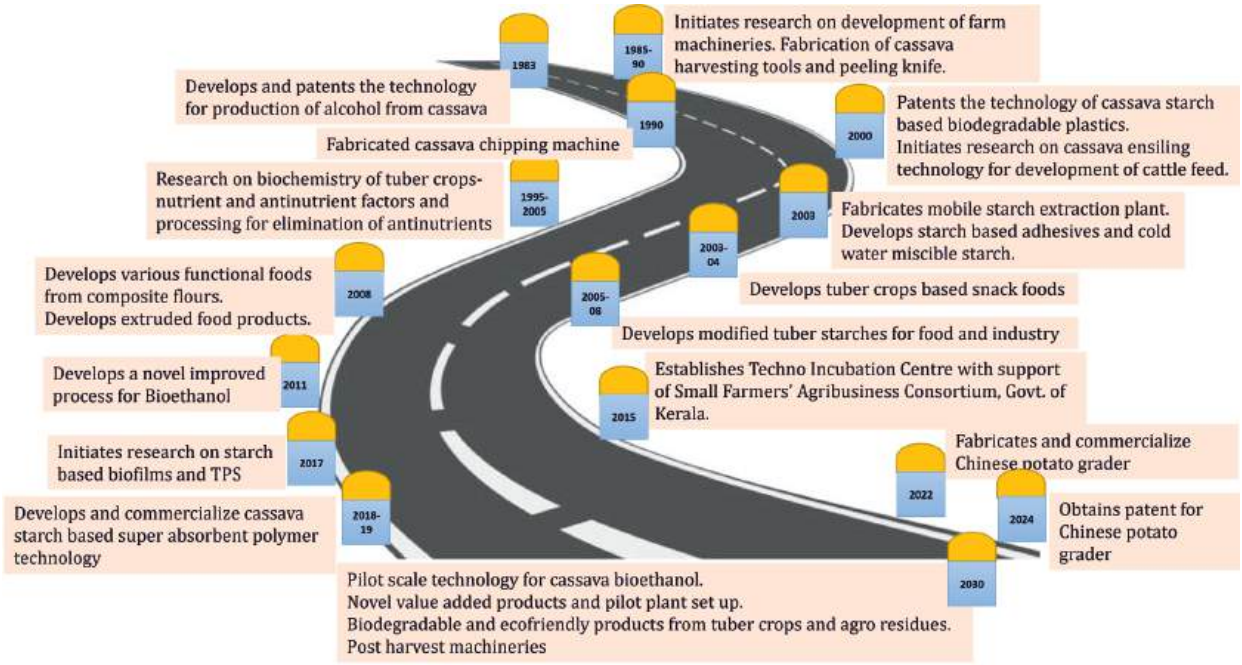
Aspirations

- Adding value to tuber crops through product diversification in food, feed and industrial sectors.
- Handholding of incubatees for establishment of start-ups and entrepreneurship development.
- Green energy and environment friendly materials from tuber crops and agro residues.
- Mechanization of post harvest operations in tuber crops.
- Addressing the chemical contamination problems in sago industry.

Action Plan

- Development of novel functional foods and industrial products from tuber crops.
- Refinement and upscaling of bioethanol production from cassava.
  Development of biodegradable and ecofriendly materials from tuber crops.
- Development of pilot plants for various value added products from tuber crops
- Development of machineries to reduce post harvest losses.
- Interventions in sago industry for developing standard operating procedures and eliminate the use of harmful chemicals.
- Establishing collaboration with industries, other ICAR institutes and national/international level organizations for developing and commercializing novel products/processes and machineries.

Achievements and Milestones



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