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Adding value to tuber crops: Unlocking new opportunities

ICAR-Central Tuber Crops Research Institute has developed a range of innovative technologies for value addition and postharvest utilization of tropical tuber crops. Rich in starch with unique physico-chemical properties, these crops are processed into extruded foods like pasta, noodles, spaghetti, kurkure-type snacks and fried products from composite flours with good nutritional and sensory quality. Cassava starch, being renewable, abundant, low-cost, film-forming and biodegradable, is a promising material for eco-friendly packaging and a key feedstock for bioethanol production. Modified starches with tailored properties further widen applications, including superabsorbent gels for healthcare and agriculture, nanocomposites for sustained drug delivery, corrugating adhesives, graft copolymers for oil drilling, and textile sizing. Anthocyanins from sweet potato tubers and leaves provide safe natural food colourants, while cassava stems and leaves can be used for particle boards and biopesticides. Thus, tropical tuber crops offer vast opportunities for sustainable food and industrial applications.

Keywords: ICAR-CTCRI, Ready to cook food, Savory snacks, Starch, Value-addition

TUBER crops are the major sources of starch and are considered as a primary and secondary food sources in tropical and sub-tropical countries. However, their short shelf life, combined with logistical issues in transportation, storage and distribution often causes major difficulties for farmers. To address these issues, processing and product diversification at the production site itself are highly recommended. Although often labeled as "poor man's crops" in rural areas, they hold immense untapped potential for conversion into commercial products for human consumption, livestock feed and industry.

TUBER CROPS FOR 'BITE TO EAT' PRODUCTS

Savory snacks

Excellent quality fried chips with light yellow colour and soft crispy texture can be made from the tubers of cassava, sweet potato, yams and aroids by different pre-treatment process and deep frying in oil. Vacuum fried chips with reduced oil content and enhanced retention of bioactive compounds were developed from coloured (orange and purple) sweet potato tubers. A variety of cold-extruded and oil-fried snack foods with desirable texture and taste such as sweet fries, *pakkavada, murukku,* nutrichips, salty diamonds, hot sticks, crisps, and salty fries can be prepared from tuber based composite flour formulated with refined wheat flour, Bengal gram flour, rice flour, spices, and condiments.

Tuber flours or starches having complex physico-chemical and functional characteristics, can be blended with wheat, finger millet, soy flour, etc., and hot-extruded to produce a range of nutritionally enhanced, ready-to-eat puffed products. Crispy snack food viz., chitchore can be prepared from the cassava tuber mash mixed with cheese, refined wheat flour, baking powder, salt, white pepper and sugar, and drying and deep fried in oil. Functional mini-*papads* with soft and crispy texture can be developed from cassava flour added with fibre or protein sources or from the composite of *Amorphophallus*, black gram and green gram flours.

Fried snacks

Vacuum fried chips

Sweet snacks

Functional cookies devoid of gluten can be developed from beta-carotene and anthocyanin rich sweet potato based composite flour containing fructo-oligosaccharide, whey protein concentrate, sucralose and maltodextrin or from taro flour with rice, sorghum and cassava flour. The bread made from beta-carotene rich sweet potato, added with psyllium husk and whey protein concentrate has high nutrient content. Muffins with high protein and crude fiber was developed from the composite flour of sweet potato, wheat flour and whey protein concentrate. The anthocyanin/beta-carotene rich cake can be made from the coloured sweet potato flour-*maida* based composite flour. The protein enriched nutria-bar can be made with sweet potato, honey/jaggery, puffed rice, oats, dhal, Bengal gram and nuts or with sweet potato flour, Bengal gram, green gram, oats and nuts.

Sweet snacks

Pre-mixed ready to cook food

The ready to use paratha mix was developed using sweet potato flour combined with multigrain, millet and dried spices. Anthocyanine rich *laddu* mix can be prepared from purple fleshed sweet potato, Bengal gram flour, sugar and cardamom. Micronutrient enriched weaning food mixes can be made by blending flours of sweet potato, arrowroot, *chuda*, malted ragi, rice, sugar, skim milk and starch. The process technology for the production of shelf stable dehydrated ready to cook flakes from elephant foot yam tubers for making *adapradhaman* or *kheer*) having comparable quality in taste and texture of the rice based flakes (*ada*) can be produced from the dough of mashed and boiled elephant foot yam tubers with wheat flour.

Elephant foot yam flakes

Cold extruded products

An array of cold-extruded pasta/noodles products with high functional value and reduced starch digestibility can be produced from tuber based composite flours. Technology has been standardised for protein rich (10-15%) cassava pasta with excellent cooking quality by adding whey protein concentrate/defatted soy flour/fish powder. Dietary fibre enriched sweet potato pasta was made by adding oat/wheat/ rice bran and it is considered as an ideal food for diabetic and obese people because of it slow digestibility. Edible gums like guar gum, xanthan gum and locust bean gum at 1% level in cassava/sweet potato-maida blends offers better functional and cooking qualities of the pasta/noodles. Low glycaemic spaghetti can be developed by fortification of sweet potato flour with sweet potato starch/banana/legume or using NUTRIOSE, a resistant starch source. Gluten-free pasta from sweet potato-rice flour mix was developed by adding whey protein concentrate and guar gum. Sweet potato-pseudo millet based pasta can be developed with millet flour, sweet potato flour, *maida* and starch along with quinoa and buckwheat flour. Functional pasta with high protein and micronutrients can be prepared from suji, amorphophallus and finger millet flour. Rice analogue was prepared from the composite flour of cassava/sweet potato, guar gum, rice flour/refined wheat flour, gelatinized starch and whey protein concentrate and the resulting product had good swelling power and low cooking loss.

Pasta and noodles

Diary analogues from biofortified sweet potato

Synbiotic ice cream can significantly enhance gut health, nutrient absorption and immune function. Two variants of synbiotic sweet potato ice creams were developed; viz., anthocyanin rich synbiotic sweet potato ice cream which is rich in anthocyanin content (12.20 mg/100 g), dietary fiber (3 g), protein content (4.18%) and abundant with beneficial probiotic bacteria (4.0×10^8 CFU/ml at end of the three month storage) and beta carotene rich synbiotic sweet potato ice cream which contains good amounts of vitamin A (455 mcg RAE), dietary fiber (3 g), protein (4.28%) and abundant with beneficial probiotic bacteria (4.0×10^8 CFU/ml at end of the three month storage). Anthocyanin rich sweet potato *kulfi* contains anthocyanin content of 12.45 mg/100 g and protein content of 3.94 % and beta carotene rich sweet potato *kulfi* contains good amounts of vitamin A (487 mcg RAE) and protein content of 4.22%.

Sweet potato ice cream

Cassava starch based industrial products

Cassava starch with unique physico-chemical, functional and rheological properties finds extensive applications in food and industrial sectors. Cassava starch in its native or modified form is largely used in paper and textile industries. Sago (*Saboo dana*) is manufactured from the wet starch by granulation, roasting/steaming and drying. Sago wafers are prepared by forming the wet sago granules in different shapes, steaming and drying.

Modified starches

ICAR-CTCRI has standardised process protocols for the production of variety of modified starches by physical and chemical methods. Cross-linked starch, oxidized starch, starch phosphate, octenyl succinate starch, starch succinate, starch citrate and hydroxypropylated starch are some of the chemically modified starches. Annealing, heat-moisture treatment and pre-gelatinization are the main processes adopted for physical modifications. These modified starches are used as food ingredient in salad dressings, canned foods and puddings, frozen foods, jellies, soups, fruit pastes. Other applications included as carriers, surgical dusting powders, absorbents and ion exchange paper, resins, and adhesive, tablet disintegrant, instant binder, etc.

Adhesives and gums

Liquid adhesives and gum pastes with improved shelf life can be made from cassava starch by cooking in water and by adding formaldehyde or copper sulphate and borax, urea, glycerol, carboxymethyl cellulose. Bench scale technologies were developed for the preparation of multipurpose binding paste, ready-to-mix two-part adhesive, corrugating adhesives, moisture resistant corrugating adhesive and alkali free corrugating adhesive dry mix.

Starch graft-co-polymers

The process for various graft copolymers of cassava starch, namely starch-graft-poly (acrylonitrile), starch-graft-poly (acrylamide) and starch-graft-poly (methacrylamide) with properties such as cold swelling behavior, high viscosity, enhanced water absorption and improved thermal stability has been standardized. The acrylonitrile based graft copolymers were found to be water insoluble with excellent thermal stability. It can be utilized in oil drilling, cotton fabric sizing and printing, water treatment for heavy metal ion removal, and as a flocculating agent. The superabsorbent polymer developed by alkali saponification of grafted cassava starch can absorb 350-400 gram water per gram dry sample in 2 hrs and is very effective in soil moisture retention thereby reduces irrigation interval.

Cassava starch based superabsorbent polymer

Starch based nanocomposites as sustained drug delivery matrices

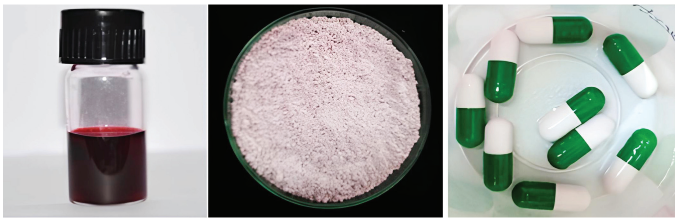
The nano-composites of cassava starch/montmorillonite is a suitable matrices for incorporating therapeutic drugs like theophylline to achieve sustained release. Similarly, starch–konjac glucomannan blend films were developed to support sustained drug release. The water-soluble curcumin incorporated into octenyl succinate cassava starch nanoparticles demonstrated improved aqueous solubility, enhanced cellular uptake, and anti-cancer potential. Pharmacokinetic studied in Wistar albino rats showed that the nanocurcumin formulation increased curcumin bioavailability by 71.27%.

Resistant starch

Sweet potato and cassava starches, when subjected to various chemical and physical modification techniques, yielded resistant starches (RS4, RS3 and RS5) with high amount of slowly digestible starch and medium glycemic index, making them suitable for formulating prebiotic, low-calorie and diabetic-friendly foods.

Natural colourants

Anthocyanins can be extracted from purple yam tubers and purple-fleshed sweet potato tubers and leaves. When encapsulated with maltodextrin through spray drying, the purified anthocyanins is stable at low temperatures, retain high antioxidant activity and serve as bio-colorants with lot of health benefits. Additionally, capsules containing coated/encapsulated anthocyanins have been developed as nutritional supplements.



Sweet potato anthocyanins in concentrate, encapsulated and capsule forms

Anthocyanin as natural food colourant

Biodegradable packaging and edible coating

Cassava starch is an important ingredient in developing biopolymer-based eco-friendly packaging materials. However, films made from native starch exhibit poor hydrophobicity and limited mechanical strength. Incorporating starches modified through etherification, esterification, double cross-linking, or enzymatic treatments into biocomposites significantly enhances the physical, mechanical and hydrophobicity properties. Eco-friendly biodegradable films of chitosan and konjac glucomannan were developed for food-wrapping applications, with granular cassava starch added to improve barrier and mechanical properties. Incorporation of nanosilver further imparted antimicrobial functionality to the films.

A cassava starch–konjac glucomannan blend was successfully applied as an edible coating for carrot slices. The coating reduced water loss and maintained visual quality better than uncoated samples during low-temperature storage. At room temperature, the coated slices showed no significant color change even up to 21 days, after which gradual changes were observed. Additionally, the coated samples exhibited reduced microbial growth during storage

Cassava for bioethanol

Cassava, owing to its high starch content and ability to grow well in different agro-climatic conditions is a promising feedstock for bioethanol production. Cassava tubers, dried chips/flour and starch can be used for ethanol production. The conventional three-step process (liquefaction, saccharification, and fermentation) yields about 300-450 liters of ethanol per tonne of starch. In contrast, a modified process with a shorter processing time of just two days (compared to five in the conventional method) achieves yields of 450-680 liters per tonne of starch

Value-addition to cassava by-products

Particle boards have been developed from cassava stems, either alone or in combination with other agro-residue fibers, using synthetic resins such as urea-, phenol-, or melamine-formaldehyde. The resulting boards exhibit properties that conform to BIS standards. The toxic principles (cyanoglucosides) present in cassava leaves/tuber rinds has been segregated and developed into potent bioformulations against a spectrum of insect pests in horticultural crops such as borer pests like pseudostem weevil (*Odoiporus longicollis*) and rhizome weevil (*Cosmopolites sordidus*) in banana, sucking pests like aphids, thrips, scale insects and mealy bugs in vegetable crops.

CONCLUSION

Tuber crops are often labelled as "poor man's crops", however, they possess significant untapped potential in food and industrial applications. The agro-industrial transformation of tuber crops, driven by advanced processing technologies, effective marketing strategies and strong institutional support can enhance food security, ensure fair returns for producers and generate rural employment. Tuber crops, from its current status as subsistence or livelihood security crops, can be effectively transformed into high-value commercial crops if innovative technologies are explored and applied for their post-harvest management and value addition.

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