11. Post-harvest Management and Value-addition

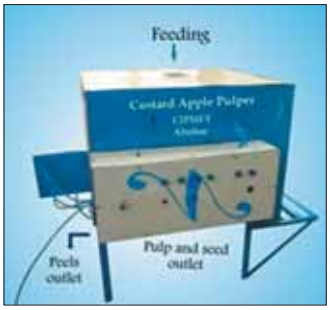
Post- harvest management and value-addition has the potential to reduce losses in food, enhance food nutrition, improve food quality, utilize by-products and improve income through employment opportunities. Development and commercialization of tools, equipment for primary and secondary processing of farm produce, process protocols for value-added products, methods for quality evaluation of foods have been attempted. The current research efforts are targeted for development of equipment, process protocols and value-added products for farmers, entrepreneurs and other stakeholders involved in the value-chain.

Equipment

***Makhana* popping and decorticating machine:** Manual processing of *makhana (*gorgon nut) involves cleaning, sun-drying, size-grading, roasting in the traditional earthen-pots or cast-iron pans over fire for 4-5 minutes; this is tedious, time-consuming, energy-intensive and involves lot of drudgery, and also requires skilled manpower.

A *makhana* popping and decorticating machine designed with a capacity of 35-40 kg of raw wet-nuts/h has a popping efficiency of more than 90%. The machine consists of a roasting and a decortication/popping unit. In the roasting unit, *makhana* is heated at 200 to 300ºC, and then conveyed to decortication /popping unit. The popping unit consists of a casing and an impeller assembly with a hard impact surface. When hot nuts strike the impact surface, shells get broken, and due to sudden drop in the pressure, kernels pop-up. The design of this machine has been licensed to M/s Jwala Engineering and Consultancy Ltd, Ambala, for mass manufacturing and marketing.

Automatic custard-apple pulper: The pulper performs three functions— fruit-cutting, fruit-scooping and pulping. Fruit- cutting part of the machine has two opposite rotating rollers with fruit- holding cups. Fruits are cut into two halves by a stainless-steel knife. The cut-halves are inverted and moved on to a stainless steel sieve and are pressed by a pressing plate. The seeds pass through the sieve, and peel remains on it.



Custard-apple pulp scooping machine

Custard-apple pulper

A pneumatically actuated scooping plate, running below the sieve, removes pulp collected in the tray. The peels are removed from the sieve with a sieve-cleaner. The capacity of the pulping machine is 120 kg/h with a recovery of 94 % pulp (coarse pulp 70-72% and fine

Foldable plastic boxes for safe fruit transportation

Foldable plastic- box has individual cell size fixed on the basis of the average size of the fruit to be packed and transported. For sapota transportation, size of the plastic box is 390 mm × 325mm × 245 mm (total volume 0.031 m^3), and cell size is 60 mm × 60 mm × 55 mm. Fruits are arranged in four layers in the box. Each layer is separated from the adjoining by a plastic sheet. Number of cells per layer is 30 and the total number of cells per box is 120. For air circulation, 5- mm holes are made on the sheet in each cell with the outer sheet having perforation of 0.90 %. The box is made with full-corner reinforcement to bear load of the upper boxes during transportation. The folded dimensions of the box are 725 mm × 585 mm × 30 mm (total volume 0.013 m^3).

A comparative study of the newly developed foldable plastic boxes with corrugated-fibre board boxes was done in transporting sapota-fruits from Junagadh to Jamnagar and from Jamnagar to Junagadh. The overall cost of packaging, handling and transportation of sapota over 300 km in the foldable boxes was ` 2 per kg of fruits. Hardness, firmness, bio-yield point, rupture force and marketable fruits were found better in newly developed boxes and losses in terms of bruising, cracking, impact damage, ripening and decay were also minimal in foldable plastic boxes.

Foldable plastic box with cells

pulp 28-30 %). The design of machine has been licensed to M/s NEXTGEN Drying Systems, Pune.

Cryogenic grinding system for spices: The conventional grinding of spices results in an inferior quality dark powder of coarse particles with lesser volatile oil. Moreover, it is difficult to operate conventional grinder continuously due to choking of powder over the grinding surface. To overcome, these problems, a cryogenic grinding system has been developed that consists of a precooling unit (a screw conveyor assembly and a liquid-nitrogen dewar), a grinding unit (pin or hammer mill), a cyclone separator to collect fine powder, a sieving unit for grading powder, and a control panel to regulate temperature, speed of screw assembly in the precooling unit and of grinder. All contact parts of the machine are made of stainless steel (SS-304).

Depending on the spices, capacity of the cryogenic system is 30-40 kg/h. The system was tested on black pepper, coriander and fenugreek seeds at 10°C and –50°C. At –50°C, about 25-30% higher volatile oil content could be obtained in ground powder in comparison to 10°C. Cryogenically ground powder also showed finer particle size, lighter colour, and higher retention of total phenols, and flavonoid and antioxidant contents. The design of the cryogenic grinding system has been licensed to M/s Spectra Cryogenic System Pvt. Ltd.

CIRCOT-phoenix *charkha:* The *charkha* has been found efficient for spinning coarse, long-staple fibres of banana pseudostem at the cottage level. It produces fairly fine yarn with sufficient uniformity from natural fibres, otherwise difficult to spin. A moderately skilled operator can produce about 4.0 kg of yarn in a day.

Yarn count from the *charkha* can vary from 150 to 600 tex. A trial was carried to produce various types of yarns; their tensile characteristics were found at a par with mill-made yarn. With this *charkha*, a yarn count as fine as 149 tex (4s Ne) could be produced for making home - furnishing fabrics.

Handloom for weaving jute-based ornamental fabric: An upgraded handloom has been developed with double jacquard system for weaving jute-based quality fabric, and especially ornamental fabric. This handloom has the following special features: Holding capacity of cloth- roller is more than 50 metres of decorative jute fabrics of 400 gram per square metre; has bigger shuttle box (58.5cm ×5.7cm) and slay-race (6.5 cm wide) to run large shuttle (up to 40cm × 5cm) that can accommodate larger (up to 18 cm length) pirn. The yarn content in the pirn increased to 24 g (almost 400% higher) as against 6.5 g used in the traditional

Mobile poultry processing unit-cum-retail meat stall

A mobile poultry processing unit-cum-retail meat stall designed is found suitable to produce safe and hygienic meat with the latest quality norms.

The stainless steel unit weighing 500 kg is of 2,410mm × 1,345mm × 2,058 mm, and costs approximately ` 5.50 lakh (2012-13). Its capacity is 35-40 birds per hour. It consists of two water tanks, bleeding cones and troughs, a scalding tank, a de-feathering machine, a carcass washing unit, a teflon board for cutting carcasses, an insulation box, crates for holding 50 line birds and work area for preparation of value-added products.

Success story

Gum -inducing technique for increasing income of farmers

A method of tapping gum from *A.senegal* using gum inducer (ethephon), which has been in use since 2008-09, has been developed. Farmers of 45 villages of Chauhatan and Baytu tehsils of Barmer district; Shergarh and Phalodi tehsils of Jodhpur district; and some villages of Nagaur and Pali districts have adopted this gum- inducing technology. Total number of 30,000 trees were treated with gum inducer during 2012-13, resulting in production of 12 tonnes of gum Arabic. This year, the average rate for gum Arabic was ` 700 per kg in the local market. Thus, farmers earned revenue of ` 8,400,000. Besides *A. senegal,* other gum- yielding trees —*A. tortilis, A. nilotica, A. leucopholea, Prosopis cineraria, P. juliflora, Annogesius rontundifolia,* — are also being treated by villagers.

Gum arabic production and economic returns in 45 target villages of Barmer, Jodhpur and Nagaur districts of arid western Rajasthan

Particulars	Year					Total
	2008-09	2009-10	2010-11	2011-12	2012-13	
Number of *A. senegal* trees treated (in thousand)	12.1	20.95	22.61	27.5	30	113.16
Production of gum Arabic by farmers (tonnes)	5.45	10.48	7.67	11	12	46.58
Total income earned by farmers (Rs in lakh)	27.23	52.38	38.33	77	84	278.93
Revenue generated by CAZRI (Rs in lakh)	1.21	2.1	2.25	2.75	3	11.3

cotton handloom; has automatic take-up and let-off arrangement; has double beam arrangement for different quality and fineness of warp yarn; and has special harnessing arrangement for coarser jute-yarn use in warp.

Continuous hot- air puffing system for oil-free puffed, ready-to-eat snack-food: The continuous operation of the system with recirculation of hot- air results in five-fold increase in capacity and 60 % reduction of heating- load over the existing conventional batch- type puffing system. The cost of the machine is ` 30,000, and the cost of the product works out at ` 125 to 140 / kg. The system operates with 1- hp blower and 8 -kW heaters, and has an input capacity of 6 kg/h and an output capacity of 5.0 to 5.5 kg/h. It prepares oil-free and shelf-stable puffed ready-to-eat snack-food from rice-mill and *dal* mill by-products. The optimum composition for production of puffed snacks is 80% rice brokens plus 20% dal brokens. Cold rectangular extrudates are puffed at 250°C, and the end- product has a shelf- life of 5 months.

Pilot plant for solid and liquid jaggery: The pilot plant consists of a three-roller crusher (capacity 800 kg/h), an electric motor (7-hp), a furnace with four pans, a stainless steel juice tank (500- litre capacity),a stainless steel trolley (200 kg), a juice pump, water pump and a weighing balance. Benefit: cost ratio, payback period and break-even point for preparation of solid jaggery were, respectively, 1.51, 1.15 years and 53.6 %, showing viability of the unit.

Process protocols

Tender coconut- husk extract for cotton-textile dyeing: Cotton-fabric mordanted with tannic acid and alum was dyed with extract from tender coconut- husk to reddish- pink shade at an alkaline *p*H. Treatment with copper sulphate or ferrous sulphate as secondary mordants improved shade. Dyed samples showed good grades for light shades, and very good grades for washing and rubbing. But, need improvement in fastness to perspiration, as colour changes to darker shades.

Samples dyed in rope-dyeing machine

Scale-up trials of the process were carried out with rope-dyeing machine and in rotary pressure vessel, and uniform colour dyeing was obtained on cotton- textiles with good colour strength (K/S) and UV protection (UPF).

Cotton- textile flame-retardant finishing with banana-pseudostem sap: Bleached and mercerized cotton-fabric mordanted with tannic acid (5% owf) and alum (10% owf) was treated with pseudostem sap in alkaline *p*H at the near boiling temperature with continuous shaking and then drying in an oven. The fabric showed good flame- retardant property, as its limiting oxygen index improved by 1.6 times of the untreated control to reach 31. Thermogravimetric analysis showed pyrolysis of the treated fabric being started at 240°C (as against 320°C in control), and it was much slower. Fixation of nitrogenous and phosphatic substances and minerals of the sap onto the fabric has imparted flame- retardant property. Finished fabric was light yellow and showed very good UV protection with a UPF of 50+.

Dry-retting of jute using pectinolytic fungi: Conventional retting of jute- plant for producing good quality fibres requires 20 times water of the biomass. A pectinolytic fungal culture has been developed for dry retting. These fungi function in aerobic condition, and produce alkaline reaction during retting by

producing a special enzyme pectin lyase and a common enzyme exo-polygalacturonase, and require no water for retting. Even methane or other obnoxious gases are not produced during fungal-retting.

Tensile strength at break, work of rupture, hairiness index, lustre percentage and thick and thin place ratio showed yarn of reasonably good quality for textile-use and for handicraft.

Fibre quality of 90-day-old plant by fungal dry-retting

Fungus	Root content (%)	Fibre strength (g/tex)	Fibre fineness (tex)	Fibre grade
Aspergillus tamarii	5	22.7	2.1	TD-5, 60% up
Aspergillus flavus	5	24.4	2.8	TD-4
Aspergillus niger	5	22.7	2.7	TD-5, 90% up
Sporotrichum thermophile	5	24.2	3.0	TD-5, 50% up

TD – *Tossa deshi*

Chemical-retting of raw-coconut fibres: The chemical process involves treatment of fibres with a combination of aqueous solution of sodium sulphide, sodium hydroxide and sodium carbonate at 90–100°C for 60–120 min. Coconut fibres softened up to 50% as compared to raw un-retted fibres.

Early detection of deadly lac insect parasitoid: *Aprostocetus purpureus* is the principal cause for pre-summer mortality of *rangeeni* lac, leading to crop failure. A PCR- based method facilitates early detection of parasitoids in lac-insect culture, using 18S rDNA primers specific for amplifying *A. purpureus* DNA. Early detection enables adaptation of timely management practices to save lac- crop.

Banana: Robusta banana harvested at 80% maturity could be stored for 72 days at Modified Atmosphere Packaging (3%O_2 + 10% CO_2). *Udhayam* banana harvested at 75% maturity had 60 days shelf-life at 13.5°C storage temperature when compared to 14 days at ambient room temperature. *Rasthali* (*Mortman*) banana could be stored up to 102 days at 13.5°C with improved post-harvest handling techniques. *Poovan* banana ripened with 100ppm ethylene treatment for five hours in the ripening chamber at room temperature was highly acceptable with a hedonic scale of 7.41.

Guava: With two per cent chitosan coating, unripe green Allahabad Safeda fruits could be stored for three weeks at 8°C temperature without affecting quality.

Bael: Technology for bael cider (4% alcohol, 16.9^{0}Brix TSS, 0.63 % acidity and 266 mg/100ml polyphenols) production having natural flavour and taste using *Saccharomyces cerevisiae* through alcoholic fermentation was standardized. It could be stored for one year at room temperature.

The powder prepared from bael pulp could successfully be stored up to five months at room temperature and RTS prepared from this powder was highly acceptable.

A rapid LC-ESI-MS/MS method was developed for simultaneous determination of five bioactive molecules, i.e. umbeliferone, psoralene, marmin, imperatorin and skimmianine in bael root and stem bark extracts, the content being higher in roots.

Jackfruit: Fresh flakes (without seeds) of ripe jackfruit were preserved by hurdle processing. The yield of fresh flakes was 28 %, loss in weight of flakes due to blanching 22.73% and the yield of finished product 51.79% of prepared flakes and 14.5% of whole fruits. It had 19-21.0% moisture and 6 months shelf-life.

Grapes: Early pruning with higher crop load (40 bunches/vine) caused reduction in acids (5.90 g/litre) in Cabernet Sauvignon berries. Degree days and sunshine hours were positively correlated with TSS and negatively with acidity. Raisins prepared from Thompson Seedless dipped for four minutes in 25 ml ethyl oleate + 40 g potassium carbonate/litre solution were of better quality. Better quality wines with respect to acidity (pH 3.63), total acids (4.48 g/litre) and malic acid (2.60 g/litre) were produced from berries harvested from late pruned vines. Early pruned vines produced wine having high colour intensity (3.71), tannins (1096.87 mg/litre), total polyphenol index (274.88) and malvidin-3-glucoside (348.04) as compared to later pruned ones.

Litchi: Post- harvest losses in litchi at various stages of delivery chain were quantified in the samples from retailers and venders. It accounted sunburn (1.5- 44.5 %), cracked (0.5-14.0 %) and physically or mechanically damaged (nil to 44.1%) fruits during growth to harvesting. Three fungal pathogens (*Alternaria* sp., *Colletotrichum gloeosporiodis* and *Aspergillus niger)* were identified causing post-harvest losses. In storage, sulphited fruits were spoiled due to *Alternaria* sp.Fruits treated with Carbendazim (0.05%) + citric acid (2%) + KMS (500ppm) and chitosan (1%) and packed in recycled poly bag (doubled) resulted in minimum fruit loss (6.57%) under ambient conditions on 4th day of harvesting, followed by LDPE packed fruits (7.77%). Post harvest losses of fruits transported to New Delhi market on third day of harvesting was reduced due to packing in polyethylene bags plus CFB boxes (15.6%) as compared to traditional packing (26.56%. Fermentation of litchi juice at 15°C retained freshness and fruity aroma like methyl propanol, ethyl ester (42.5mg/litre) and total acetate (2.40mg/litre) wine due to low sugar fermentation rate (0.61g/litre/hour). Maximum damage in nuts (76.04%) was observed due to pre treatment with boiling water followed by KMS (0.1%) and citric acid (2%).

Pomegranate: The maturity indices of pomegranate Bhagawa were 180 days after setting or 15.9°Brix TSS, acidity (0.48%) and TSS/acidity ratio (33.2), while for Ganesh, the fruit maturity indices were 150 days after setting or TSS (16.1°Brix), acidity (0.45%), and TSS:acid ratio (35.7) under Solapur conditions.

The technique of preparing ready-to-serve (RTS) beverage from pomegranate Bhagawa and Ganesh was standardized. The technique for wine (8-11% alcohol, 0.85g/100g acids and 11.5°Brix TSS) preparation through fermentation of juice was standardized.

Apricot: Type of material and sugar solutions significantly affected the time required for dehydration (15±2% moisture level). Half fruits without stone (HWOS) took minimum time for dehydration as compared to whole fruits without stone. Half fruits without stone dipped in 55° Brix sugar solution and pre-drying treatment with 1% KMS took least time (37 h) for drying up to 15±2% moisture. Maximum dehydration (moisture loss) during osmosis (dipped in sugar solution) was recorded in case of half fruits without stone treated with 1% KMS and dipped in 55° Brix sugar solution. Total soluble solids, acidity and ascorbic acid contents varied significantly due to type of planting material, sugar solution and treatment with KMS (1%). Maximum TSS (24.2°Brix), acidity (0.37%) and ascorbic acid (17.5 mg/100 g) were recorded in HWOS dipped in 55° Brix sugar solution and pre-drying treatment with 1% KMS.

Plantation crops: A simple technique to collect fresh and hygienic inflorescence sap (*neera*) from coconut and a process for making natural coconut sugar and jaggery from fresh sap was developed. Biochemical analysis indicated lower free fatty acid content, higher polyphenols and 9 times higher antioxidant activity of virgin coconut oil (as catechol @ 18mg/100g oil) when compared with traditional (2mg/100g oil) coconut oil.

Brinjal: After 12 days of ambient storage, minimum decrease in fruit firmness was recorded in PEG used as humectant and sodium alginate (SA) based carnauba wax emulsion as surfactant, followed by commercial 'Niprofresh' carnauba wax emulsion (8.56-4.95 N) and sodium dodecyl sulfate based carnauba wax emulsion. During storage for 12 days, maximum total phenol content and antioxidant activity was retained in PEG and SA based carnauba wax treatment and it can be adopted for enhancing storage life of highly perishable vegetables.

Chilli and capsicum: Green chilli packed in 3 kg CFB boxes and over-wrapped by shrink film wrapping could be stored for three weeks at 8°C with farm freshness and weight loss of 4.9 % as compared to 9 % loss in non-wrapped chilli. Capsicum could be stored in harvest fresh condition without shriveling and with maintenance of firmness for seven days in high humidity, low cost polyethylene storage tent with a weight loss of only 2.2% compared to 8% within three days in control (25 -30°C and 40-52% RH).

Carrot: Large variability in total phenols (7.98-291.48 mg/100g) and flavonoid (2.49-111.66 mg CE/100g) in 21 Indian carrot varieties was recorded. Maximum anthocyanin (243.05 mg/100g) was observed in black genotype Pusa Asita. Black Beauty, Pusa Asita, Pusa Meghali, Pusa Rudhira and Pusa Vristi varieties had higher antioxidant. Anthocyanin derived from black carrot exhibited higher stability as compared to black grape for lower rate constant, higher half-life and activation energy.

Onion: Application of CIPC @ 2% at 75 DAT reduced sprouting in *kharif* produced onion but was ineffective in *rabi*, whereas $CoCl_2$ was effective in arresting sprouting in *rabi* produced onion. Post-harvest application of ethanol (2%) was superior in reducing post-harvest physical losses in *rabi* onion up to four months.

Tuber crops: Gluten-free, low glycemic and functional pasta from cassava, low glycemic spaghetti from sweet potato; protein and fibre fortified pasta from *Amorphophallus* and yam were developed. Stable natural colour-cum-health protectant from *Dioscorea alata* and sweet potato was developed. Processes for the production of de-branched starch with high resistant starch content, neageli dextrins and lintnerized starches were developed. A technology was perfected for production of porous super-absorbent polymer from tuber crops.

Potato: In seed potato, treatment of 1,4-dimethylnaphthalene (20 ppm) was sufficient to delay sprouting under diffused light storage.

Floriculture: In gladiolus, longer vase-life (12-14 days) was observed in Invitatie, Flevo Souvenir and Argentina; medium (9-11 days) in Fidelio, Ocilla, Snow Princess and short (4-6 days) in Blues, Purple Flora and Chemistry varieties.

Pusa Narangi Gainda contained more carotene in comparison to Red Brocrade, Pusa Basanti Gainda and Pusa Arpita varieties.

The colour retention of dried *Helichrysum* flowers packed in polythene sleeves and kept at room temperature was better even after one year of storage, whereas slight discolouration was observed in *Limonium* and *Brumus*.

The cut rose stems of First Red variety treated with 50ppm chlorine during pre-cooling showed significant improvement in opening of bud, vase-life and water absorption.

Gladiolus Punjab Dawn was effectively stored for seven days under MA (3-4°C in PP-100 gauge packaging).

Spices: In fenugreek, diosgenin content in seeds of RMT 1, RMT 305 and AFg-3 genotypes was significantly more (2.1-2.5%) due to cryogrinding as compared to non-cryoground samples (1.3 to 1.5%). There was positive effect of cryogenic grinding on total phenolic, flavonoids, oil content and antioxidant activity of fenugreek and coriander powder during storage.

Rapid detection of food pathogens by polymerase chain reaction: PCR protocols for detection of five important food pathogens were standardized and developed. The genus specific primers were designed by targeting *Hyp* gene for *Campylobacter jejuni*, *prfA* for *Listeria monocytogenes*, *stx* for *Escherichia coli O157:H7*, *invA* for *Salmonella* spp., *nuc* for *Staphylococcus aureus*.

This technique can detect simultaneously *Escherichia coli O157:H7,* S*almonella* spp., *Staphylococcus aureus, Campylobacter jejuni* and *Listeria monocytogenes* within 24 h**,** while the conventional methods require more than 72 h. Organisms could be detected with meat sample of 25 g, and analysis cost was almost half in comparison to conventional methods.

Size of the amplified PCR products in 2% agarose gel electrophoresis was 500 bp for *Campylobacter jejuni,* 290 bp for *Listeria monocytogenes,* 632 bp for *Escherichia coli O157:H7,* 570 bp for *Salmonella* spp. and 384 bp for *Staphylococcus aureus.*

Bioactive properties of camel milk: The antioxidant property of camel milk was significantly higher in fermented milk compared to raw milk. The antimicrobial activity of fermented milk supernatants was 100% inhibitory at 5% concentration level against *Escherichia. coli*.

Detection of adulterants in milk: *L. monocytogenes* causes human listeriosis with high rate of mortality. Recently FSSAI implemented a "zero tolerance" policy for monitoring *L. monocytogenes* in dairy products. In view of food safety concern, NDRI developed the new technology which has immense industrial application. Assay can confirm the presence of *L. monocytogenes* within real time of 4.30 ± 0.10 h after initial pre-enrichment of milk samples in novel selective medium, i.e. LSEM for 18 or 24 h. Appearance of black colour indicates the presumptive presence of *Listeria* spp. and of green colour confirms the *L. monocytogenes.* Technology was validated with raw milk, pasteurized milk, ice cream, butter, cheeses etc. Memorandum of Agreement between a commercial company and NDRI, Karnal was signed for transfer of this technology entitled 'detection of *L. monocytogenes* in milk'.

Meat storage: Fresh meat can be stored in refrigerator for 3-5 days and up to 4 months at –20°C. Technology was developed for storing meat under super-chilling (1°C) condition and vacuum packaging for chicken

Vacuum packaged super chilled chicken drumsticks

drumsticks, which can extend the shelf-life up to 30 days without freezing. This technology reduces the cost of energy and ensures availability of fresh product.

Nutrient profiles of *Sperata seenghala* and *Tenualosa ilisha* : Proximate nutrient profile of giant river-catfish *Sperata seenghala* revealed moisture, crude protein, crude fat and ash contents of 79.40 ± 0.09%, 20.06 ± 1.13%, 1.40 ± 0.79% and 0.90 ± 0.08%, respectively. In addition, the fish flesh is rich in essential amino acids histidine, threonine and leucine and ratio of essential to non-essential amino acid is 0.89 indicating its superior protein quality. The mineral profiling indicated that the species is also a good source of zinc, iron and calcium.

The fatty acid profiling of different sizes of *Tenualosa ilisha*, a highly preferred food fish in South-Asian countries, showed that medium-size fish contained highest amount of unsaturated fatty acids as well as ω-3 PUFAs, EPA and DHA and the lowest amount of saturated fatty acids (SFAs). Small-size hilsa has highest PUFA content but lower ω-3 PUFA content, and higher SFAs content than medium-size fish. In large-size fish, although ω-3/ω-6 ratio was the highest, quantitatively they contained the lowest amount of PUFAs and highest amount of SFAs. Some important features of hilsa oil like oil content, PUFA and EPA + DHA content are shown in the Table.

Nutritional information on hilsa oil (fat)	Small fish	Medium fish	Large fish
Oil content (g/100 g wet weight)	15.33 ±0.12	16.35 ±0.07	19.15 ±0.29
PUFA (% of total fatty acids)	23.78 ±0.08	22.11 ±0.25	14.75 ±0.39
EPA+DHA (% of total fatty acids)	10.90 ±0.03	11.83 ±0.09	10.24 ±0.57

Enhancing shelf life of fish fillets: Natural extracts from sage, rosemary and origano were tried for the extension of shelf life of fish fillets under chilled storage. Treated sample exhibited antioxidant effect in fillets of *giant*- travelly. Oleoresin extracts of curry leaves and cloves on chilled storage of battered and breaded black clam enhanced shelf life upto 19 days and 21 days respectively; while control samples had a shelf life of 16 days.

Value-added products

Nail polish based on natural resin: A nail- polish formulation based on the natural lac resin, gives beautiful, very glossy, hard and smooth finish on nails, and is quick to dry and is non-hazardous to health. Properties of the nail- polish meet the requirement of IS: 9245:1994.

Lac- dye-based natural *alta:* Red- coloured natural lac dye is obtained during refining of stick-lac to seedlac. Natural *alta*, IINRG-LDA-91 (Orange coloured) and IINRG-LDA-94 (Deep- red coloured) from lac- dye and other skin -friendly ingredients, has been developed.

Success story

Lac cultivation on *Flemingia semialata* for livelihood security

Flemingia semialata is a bushy lac host for lac production. *Kusmi* lac in winter season is grown without irrigation and summer lac on the host requires irrigation. Mr Barnabas Nag, a farmer from village Lupungdih, P.O. Saparum, District Khunti, raised *F semialata* plantation of 2,500 plants and started lac cultivation in 2010. For assured broodlac production in summer, he took on lease *kusum* trees from neighbouring village at 50:50 share basis. He earmarked some portion of his *F. semialata* plantation for summer season lac cultivation under irrigated conditions. Inoculation of one- year- old plants with 5 kg *kusmi* broodlac was carried out in July 2010; from which he harvested 55 kg winter season *kusmi* lac in February 2011. Since then, he has taken up lac cultivation seriously. His profits reached an all- time high after harvest of *kusmi* summer crop in 2013 when he earned ` 2 lakh from the sale of broodlac only, besides inoculating 260 kg broodlac on *ber*, *kusum* and *semialata* plants.Mr Nag also motivated 30 farmers from an adjoining village to raise plantation for lac production.

Bio-enriched compost from cotton- plant residue: A process for preparation of good quality compost in 45 days from wet cotton- stalks by using microbial consortia has been developed. It took about 60 days when cotton- stalks were dry. Under normal conditions, composting of dry stalks takes 90 days and of wet stalks takes 60 days. The NPK content of the microbial compost from the cotton-stalks was found even better than the farmyard manure.

Compost prepared from cotton biomass and FYM

Parameters	Compost prepared from cotton biomass	FYM
Cost (`)	3,200	3,000 to 3,500
NPK content (%)	1.1, 0.9, 0.5 (wet cotton- stalks) 1.43, 0.78, 1.82 (dry cotton-stalks)	0.5, 0.2, 0.5
Duration of preparation	45 days (wet cotton- stalks) 60 days (dry cotton -stalks)	120 days

Sorghum-*til laddu:* Roasted *til* and roasted groundnut are powdered and mixed with sorghum flour and milk powder. This is then mixed either with jaggery powder or sugar powder and pressed into a desired shape.

Roasted flakes *pedha*: The broken sorghum flakes are thoroughly powdered and prepared in the form of a *pedha* with a little amount of jaggery syrup. This product is suitable for diabetic people as sorghum is a rich source of dietary fibre, iron and polysaccharides.

Bran *pedha*: Bran extracted from milling sorghum is finely powdered, dried and then mixed with skimmed milk powder, sugar and ghee. The mixture is then made into *pedha* and silver-foil is pasted to make it attractive.

Success story

Enhanced income through lac cultivation

Shri Yogendra Ahir, aged 57 yrs of Banta village of Silli block in Ranchi district (Jharkhand) was earning ` 3,000 a month from a small tea stall. He was motivated for lac cultivation by fellow farmers. He acquired three *Ziziphus mauritiana (ber)* trees from his fellow farmers and inoculated them with three kg of *kusmi* broodlac in July 2011 and harvested 30 kg broodlac worth ` 15,000 during January 2012. During 2012-13, he inoculated 8 *ber* trees with lac from winter crop and harvested 65 kg lac worth ` 32,500. By adopting scientific methods of lac cultivation he has at present raised a small *Flemingia semialata* plantation, a quick-growing bushy lac host plant, with tomato as an intercrop. The lac-crop on *F. semialata* is growing well.

Low-calorie, protein-rich crackers: Low fat sweet-salty *aonla* and beetroot crackers have good protein content (16.03%) and 60% less fat. The *aonla* crackers are rich in antioxidants (117.32 mmol/100 g) and flavonoids (389.1 mg/g), besides providing fibre from *aonla*.

Pearl pop–a ready -to-eat snack: A crunchy, soft and ready-to-eat pearl pop contains 11.2% protein, 7.36% fat, 2.96% crude fibre, 72.81% carbohydrate and is rich in micronutrients, especially iron (5.02 mg/100g) and zinc (3.01 mg/100g). The total antioxidant and phytic acid contents are found to be 15.47 µmol Trolox/100g and 373.82 mg/100g (product) respectively.

Sweetened functional chocolate cheese: Sweetened functional soft cheese from buffalo milk was developed by incorporating fructo-oligosaccharide (FOS), inulin and cocoa to enhance health attributes. Its shelf life is over 4 weeks under refrigeration without any preservatives. This product could have great potential in the fastest growing functional food market. It has following health benefits.

- Polyphenolic substances from cocoa powder reduces LDL cholesterol, elevates HDL cholesterol, suppresses oxidized LDL and even prevents cancer.
- Inulin, the soluble dietary fiber, acts as prebiotic.
- FOS, a very good probiotic, helps improve immunity and is a healthy sweetener for diabetic patients.

In-line production of basundi

Basundi, a popular heat desiccated Indian dairy product, is prepared by traditional method which is a labour intensive process. Therefore, for mechanization a scraped surface heat exchanger (SSHE) was integrated with conical process vat (CPV) for in-line production of basundi.

Flavoured sheep milk: Sheep milk contains 0.20% titratable acidity, 82.82% moisture, 5.21% total protein, 0.47% total casein and 17.18% total solid. It was diluted with water (3:1) and mixed with 10% carrot pulp, sugar and cardamom to prepare natural carrot flavoured milk. The sensory attributes of the flavoured milk ranged from good to very good.

Goat milk based products: Goat milk and cream based CIRG Beans and CIRG *Khasta* were developed using pure goat milk, cream, dietary fibres and natural antioxidants. These products contain higher amount of medium chain fatty acids, which are beneficial for human health. Product scored 8 out of 9 on Hedonic scale. These products have low moisture, high protein, desirable fatty acid profile with shelf-life of four months at room temperature.

Whey based media for *Lactobacillus* spp.: Much of whey, generated as by-product from paneer, cheese and casein industries, remains unutilized leading to pollution by increasing the biochemical oxygen demand (BOD) load in dairy effluent (BOD – 40,000 to 60,000 ppm). Thus, large quantities of valuable milk nutrients present in whey are also lost. Whey was used to formulate a media for culturing, biomass production, pharmaceutical applications and enumeration of *Lactobacillus* spp. This whey based media resulted in growth of lactobacilli similar to freshly formulated whey based media and MRS medium.

Baked egg product: Process of preparing baked egg product as breakfast meal was standardized. It offers a potential market at growing fast food outlets. Baked egg was prepared using 70% liquid whole egg, 12% grated cheese and 5% skim milk solids. The cost of formulating one processed baked egg product of 15.5 cm diameter and 2 cm thickness weighing about 240 g was ` 29.70. The product was acceptable for 12 days in vacuum and 10 days in aerobic packs at refrigerated storage with satisfactory physico-chemical and microbiological quality.

Functional meat products: Functional and more shelf stable restructured buffalo meat steaks were prepared with the incorporation of antioxidant and mineral rich *amla* powder (5%).

Shelf stable meat products: Formulation and processing condition for preparation of ready-to-eat shelf stable meat slices was standardized. Developed product has high protein (>30%) and low moisture (<15%) content.

Ready-to-eat traditional meat products: The ready-to-eat (RTE) traditional Indian meat varieties such as *Rista* curry, a component of the 13 course *Kashmiri* meal called *Wazwan*, was standardized and was filled and hermetically sealed into retort flexible pouches. Shelf life study revealed that the product was stable at ambient temperature for 12 months.

Pork nuggets: Nuggets were prepared by incorporating pork with fermented bamboo shoot mince, which significantly retarded quality deterioration of nuggets during refrigeration temperature storage, especially lipid oxidation and microbiological characteristics. Nuggets with 6% and 8% fermented bamboo shoot had significantly lower TBARS values. Further, addition of fermented bamboo shoot mince at 6% and 8% levels improved their microbiological characteristics, especially the total plate count, coliform count and *Staphylococcus aureus* counts and sensory attributes, particularly flavour. Incorporation of

Success story

Popularization of value-added pork products

People of North Eastern States are predominantly non-vegetarian and pork is the most relished meat. Currently, 10 different value added pork products (viz. frankfurter, cocktail, ham, nuggets, salami of different flavor and taste) are being marketed in five different states in NE region. The pork processing plant at National Research Centre on Pig, Rani, Guwahati, is undertaking active research and training in the area of clean pork production to ensure 'Farm to Pork' quality of pork and pork products to consumers, and development and codification of procedures for value addition/packaging/transportation and marketing of pork and pork products. The Institute signed a Memorandum of Understanding (MoU) with a private company in Public-Private-Partnership (PPP) mode.

In order to meet the quality requirements and to undertake the brand building activity of the final marketable products, the pork processing plant has adopted Hazard Analysis Critical Control Points (HACCP) procedures for processing of fresh pork as well as value added pork products. The unit has obtained ISO 9001:2008 certification and Food Safety Standards Authority of India License.

Success story

Meat Processing Business

Mr Ajay Raghav, a pig farmer of about thousand pigs near Meerut signed two MoUs with the IVRI for transfer of technologies, viz. Vegetable Incorporated Meat Products and Hurdle Tech Meat Pickles. Technological input from IVRI and his own innovation helped Raghav to turn into an entrepreneur from a pig farmer. During early period of business, due to unavailability of meat processing machinery, business incubator laboratories and meat processing pilot plant facilities of IVRI were extended to him. Mr Raghav started getting higher rates for his primal cuts and started supplying to hotels in Delhi. His profit margin increased substantially and now he is a dealer instead of live pig seller.He has also entered into processed meat market launching more than 10 varieties of meat products. The business expanded and now the firm has made franchisee at several places. Encouraged with the success, Mr Raghav has signed two more MoUs with IVRI for transfer of technologies namely Chicken chips and Milk chips.

Identification of meat species by polymerase chain reaction

Molecular technique by PCR for identification of meat species in fresh, frozen, cooked and processed forms within a short time of 8 hours has been standardized and developed by targeting *mitochondrial D loop region* for chicken and duck meat, *cytochrome b* gene for emu meat and *12S rRNA gene* for quail meat, beef and pork. Minimum meat sample required for identification was 50 mg.

Using species -specific primers, the size of the amplified PCR product in 2% agarose gel electrophoresis was 442 bp for chicken meat, 229 bp for duck meat, 292 bp for emu meat, 129 bp for quail meat, 230 bp for pork and 400 bp for beef. Beef and pork specific PCR was highly sensitive for identification of meat adulteration up to the extent of 5% level.

fermented bamboo shoot mince at 8% level also increased the storage life of pork nuggets by at least two weeks.

Poultry meat wafer: A process formulation was standardized for development of shelf-stable poultry meat wafers. Based on different physico-chemical and sensory quality characteristics, formulation containing turkey and spent hen meat (70:30) was observed to be the best. Cold extrusion method followed by microwave cooking was found to be the most suitable processing technique.

Poultry meat finger chips: The optimum formulation for preparation of meat finger chips contained turkey and spent hen meat (50:50). The finger chips were rated very good by the sensory panel members. The microwave cooking method was found to be the best.

Astaxanthin: A method was developed for the isolation and purification of astaxanthin from deep sea shrimp and blood-spotted swimming crab. Astaxanthin extracted from blood-spotted swimming crab (*Portunus sanguinolentus*) showed good antioxidant activity.

Valuation of carbon stock in Sunderban mangroves

Mangroves play a significant role in carbon sequestration due to high biomass density and productivity. The economic value of carbon stored in above-ground biomass of mangroves of Sunderbans was assessed based on secondary data. The average carbon stored (tonne/ha) in *Sonneratia* sp., *Avicennia* sp. and *Excocaria* sp. was 106.35±2.86, 36.98 ± 3.56 and 19.13 ± 2.45 respectively

Anti-aging chitosan: Dietary chitosan supplementation in young and aged rats restored the depleted myocardial antioxidant defense indicating its effectiveness as therapeutic agent in treatment of age associated disorders.

Micro/nano encapsulation: Succinyl chitosan was synthesized and characterized. This polymer may serve as an effective tool in micro/nano encapsulation of nutraceuticals for controlled and efficient drug delivery.

A web based database on fish proteomics

A web-based database, FISHPROT, exclusively on fish and shellfish proteogenomics has been developed to augment future research on fish genomics and proteome, metabolic pathways, fish biomarker dioscovery etc. Currently the database contains information on muscle proteome of IMC *Catla catla*, riverine catfishes *Sperata seenghala* and *Sperata aor*, muscle and lens proteome of riverine catfish *Rita rita*, liver proteome of the murrel *Channa striatus*, plasma proteome of IMC *Labeo rohita*. The database is linked to major national and international proteomics and bioinformatics databases like NCBI, SWISSPROT, SPS, BSPR etc. FISHPROT constitutes an actual structured data repository from the researchers and acts as a global repository for archiving proteomic information on different fish species. The database can be accessed at: http://www.cifri.ernet.in/fishprot.html.

❑