10. Post-harvest Management and Value-addition

Post-harvest management is integral to agri-produce value chain for reduction in post-harvest losses and value-addition of produce of plant origin, livestock and aquaculture. A number of equipment and structures for safe handling and shelf-life enhancement of farm produce, process protocols for value-added products, novel products and technologies for farmers and processors have been developed and commercialized through the sustained efforts of the R&D institutes. The current emphasis is on development of useful farmer centric technologies for processing in production catchments, secondary agriculture and health foods.

Automated flyer spinning machine for jute-coconut fibre

Equipment

Honey filtration unit: A honey filtration unit was developed with separate heating and filtration arrangements. It has two separate sensors for controlling the temperature of heating water and honey in the main chamber and its performance was evaluated under different process conditions. The capacity of the machine is 50 kg of raw honey/batch. Heating and filtration takes about 100 and 150 min respectively. No significant difference in biochemical quality attributes, viz. reducing sugars, moisture content, acidity (formic acid %), *p*H and total soluble sugars, was observed in comparison to commercially processed honey. It was observed that the process of filtering reduced microbes. Cost of the honey filtration unit is ₹ 35,000, while the cost of operation is ₹ 2/kg of honey.

Peeler for dehydrated garlic flakes: A peeler for dehydrated garlic flakes with capacity of 50 kg/h was developed. It detaches and separates peel from dehydrated garlic flakes. The machine consists of a scrubber made of canvas strips which rotates in a barrel. Peeling takes place due to abrasion and friction. An aspirator sucks the lighter peel while the dehydrated garlic flakes are obtained through the discharge trough. Cost of the machine is ₹ 20,000 including motor. The cost of operation was observed to be ₹ 55/100 kg of dehydrated garlic flakes. The machine results in saving of almost 70% in operational cost over conventional practice.

Cashewnut drum roasting machine: A drum roasting machine of 40 kg/h capacity for raw cashew nuts was developed. Optimum combinations of temperature and time for roasting of large, medium and small size kernel were observed to be 475°C and 35s, 460°C and 40s, and 415°C and 48s respectively.

Automated flyer spinning machine: An automated flyer spinning machine was designed for spinning of jute-coconut fibre-blended yarns. Programmable logic control system for motion transfer was adopted in the machine to reduce number of gears and for easing of the change of machine parameters (speed, attenuation and twist), thus reducing the down time. The system is energy-saving, requires low manpower and makes less noise. Speed of spinning spindle was achieved up to 3,700 rpm. The machine is low priced compared to the conventional one available for jute. The machine is also suitable for producing 100% jute yarns.

Rotating flat system for CIRCOT Minicard: A novel power-driven sliver making machine, called CIRCOT Minicard, was developed. The machine has a sliver production capacity of 1–2 kg/h. The machine is fitted with a rotating flat system to improve its efficiency and performance. The modified machine could be run at a stretch for eight hours with a production of 2 kg/h sliver. The sliver produced was uniform with reduced trash content and free from neps and imperfections. The yarn produced from the sliver was found to have optimum strength for the given count and suitable for use by the rural industry.

Fibre seggregator machine for coconut fibres: A fibre segregator which is first of its kind in the country, can segregate fibres based on their fineness. Coarser fibres above 350 microns produced by the machine can be used for the conventional product manufacture. The fibres with medium fineness of 250–350 microns and finer fibres of less than 250 microns can be used for novel value-added textile products. The output of this machine presently is around 12–15 bales (one bale = 35 kg)/8 h. About 175 kg fine fibres can be realized from 15 bales of coconut fibres during segregation. This has opened up a new avenue for utilization of finer coconut fibres for value-added products, thereby enhancing the export potential, apart from providing additional income to the stakeholders in the value chain.

Winnower-cum-cleaner grader: The plastic-body pedal-operated winnower-cum-cleaner grader was

Cholesterol estimation

In *ghee*: A method was developed to estimate cholesterol in *ghee*, using *O*-phthaldehyde (OPA) reagent.

Benefits: Saponification of fat is achieved in 20 min.; very small amount of fat is used for saponification, and unsaponifiable material is extracted in single extraction; Small amount of extraction solvent (hexane) is used unlike conventional saponification method; It does not involve use of acetic anhydride (a controlled item) unlike Liebermann- Burchard reagent based method; The recovery of the method is 96.68 to 98.62%.

In milk fat: A simple and rapid method was developed for cholesterol estimation in milk fat using enzymatic diagnostic cholesterol estimation kit.

Benefits: The recovery of the cholesterol using developed method was 98.6 to 99.8% and comparable with that of direct method of cholesterol estimation using LB reagent; The method can be easily adopted for cholesterol estimation in fresh as well as heated milk fat samples; The method is useful to serve as a substitute for acetic anhydride, which has become a limiting factor in cholesterol estimation by commonly employed LB reagent method.

developed and fabricated after incorporation of various components using FRP sheets. It resulted in reduction in weight (from about 100 kg to 60 kg) and mechanical vibrations in comparison to the machine with fans of MS sheet of the same size and shape. Crops like wheat, rice, maize, pigeonpea, lentil, redgram, soybean, horsegram, mustard, barnyard millet, sorghum and pearlmilet have been tested after modification. The cleaning and winnowing efficiency was observed to be in the range of 94–97% and 96–98% respectively.

Digital radiography, CT and MRI: Digital radiography, CT and MRI were employed to detect internal physiological disorders like spongy tissue in mango, non-destructively. CT technique could also be used to assess maturity of fruits. CT number was correlated with biochemical properties on intermediate storage days and a good correlation was found between CT number and titrable acidity, *p*H and total soluble solids. CT number could be used as an indicator for maturity change. These imaging techniques could detect the presence of seed weevil in mango samples which is extremely difficult to judge by means of simple visual observation.

A digital radiography setup consisting of an X-ray tube, line-scan camera and related controls were developed. The setup is housed in a radiation protective enclosure designed to reduce the energy of the scattering radiations to a safe limit, i.e. to an extent of 1×10E-08 times.

Groundnut kernel de-skinner: De-skinning of groundnut kernel is required for making value-added dairy analogue products like groundnut milk, butter, curd, *paneer*, etc. A groundnut de-skinner having overall dimensions of 1,020 mm × 620 mm × 800 mm was developed. It works on the principle of abrasion and friction and is operated by a one hp motor. The capacity of the machine is 60–75 kg/h. The de-skinning efficiency and recovery of whole kernels were observed to be 60–70% and 35–40% respectively. The approximate cost of the machine is ₹ 25,000.

Continuous feed type *Aloe vera* gel extractor: To improve the gel extraction capacity, a power-operated unit of *Aloe vera* gel extractor was developed. The extraction equipment consists of a set of two pressure rollers on the top and a set of two rollers at the bottom on a frame above an endless belt, to flatten the *Aloe vera* leaf fed between rollers. The gel is directly collected in the tray which is partially filled with clean water. The top and the bottom leaves are collected separately. The capacity of the motorized equipment is about 200–225 kg/h (900–1,000 leaves/h). The machine-peeled gel contains only 1.0% aloin when compared to 1.99% by hand peeling and is within the safe limit.

Copra drier: Coconut biomass fired copra dryer was developed which helps in saving time, energy and manpower, thereby enhancing the net returns to farmers. In comparison to solar dryer and open sun-drying, it saves 50 and 37% of total drying time respectively. The sizes of copra dryers are available for drying of 250 or 500 coconuts. Its approximate cost ranges from ₹ 35,000 to 50,000 depending on size.

Process protocols

Process for high quality soy butter: Process technology for production of soy butter from roasted whole soybeans was developed. The process requires soaking, blanching, roasting, and milling of soybean. The soy butter contains 37.6% fat, 39.1% protein, 37 ppm trypsin inhibitor, no artificial preservatives, good emulsion stability and colour attributes. It is remarkably similar to peanut butter in taste and texture but has significantly lower total and saturated fat as compared to peanut butter (50% fat) and is cholesterol-free. The

Success story

Iron fortified biscuits from a composite dairy-cereal mix

Biscuits from composite wheat-pearl millet flour in combination with valuable dairy ingredients such as whey solids enriched with a suitable iron fortificant, selected on the basis of sensory evaluation was developed. The iron fortified biscuits contain 6.53 mg iron per 100 g, 18.81% fat, 12.23% protein, 1.13% ash, 1.42 crude fibre, 3.2% moisture and 63.28% carbohydrates. Their shelf-life is four months without any significant change in the sensory as well as nutritional attributes. *In vivo* trials on Wistar rats indicated that the iron fortified biscuits helped maintain hematic status of normal animals and repair of anaemic animals. The hemoglobin concentration (mg/dl) increased by 25% and 70% in normal and anaemic rats respectively. Ferritin concentration in the blood plasma also increased. The manufacturing cost of the product was ₹17/100 g of the product.

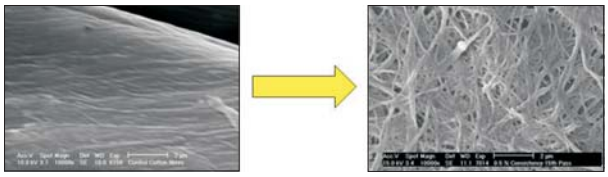
butter has a shelf-life of 45 days under ambient conditions and 60 days under refrigerated conditions. Soy butter, being nutritionally superior (higher protein, lower fat) to peanut butter and also free from peanut allergens, is recommended for consumption as a nutritious food.

Biochemical indicator of moisture-induced stress on lac host *ber*: Proline level in bark and leaves of the major lac host, *ber (Ziziphus mauritiana),* was found a good indicator of plant stress, which in turn affected lac insect survival and lac production; a negative correlation between proline content and lac insect survival was found. Irrigation led to lower proline level in *ber* plants, resulting in better survival (giving 80% more lac yield over control) of lac insect. Monitoring proline level in the host plant would thus be useful in management of stress-related factors to enhance lac productivity.

Enhancement of shelf-life of soy paneer *(tofu)* and soy milk through application of selected techniques of preservation: The main constraint in popularization of *tofu* has been its poor keeping quality of few hours (3–4 h) at ambient conditions of storage and a few days (four days) under refrigeration. Shelf-life of soy paneer was enhanced through packing it in retortable pouches and autoclaving. The extended shelf-life is 18 days at room temperature and 45 days under refrigerated conditions.

Plastic packaging for freshwater fishes: Presently, freshwater fishes are being marketed as whole fish in the fish market. PE, PP and laminated PP packaging materials were evaluated for rohu and catla fish chunks treated with spice mix nisin and pro-biotic cultures like *L. casei*, *P. pentosaseus, L. bulgaricus* and *S. thermophilus.* These treatments enhanced the keeping quality of the fish patties up to 12 days at chilling (5 ± 2ºC) and up to one month in freezing (–20 ± 2ºC). Laminated PP packaging materials were found to be most suitable for both vacuum packaging and MAP for ready-to-eat and ready-to-cook fish patties and showed the enhanced keeping quality during chilled and frozen conditions up to three months. Round polypropylene rigid containers with lid having 500 micron thickness were used for packaging of fish cut-up parts, fingers, chunks and nuggets. It maintained the hygienic and keeping quality for seven days and three months, respectively, under chilled and frozen conditions.

Cellulose nano-fibrils from cotton fibres: The short staple cotton fibres were converted to cellulose nano-fibrils by a refining process after pre-treatment with zinc chloride and cellulose enzyme. While the cotton fibres required 30 passes through the refiner for production of nano-fibrils, pretreated cotton fibres required only 15 passes. The cellulase enzyme hydrolyzed the surface molecules in cotton fibres while zinc chloride acted as a swelling agent, these pre-treatments saved the energy consumption to the tune of 50 and 40% respectively. The diameter of nano-fibrils obtained from untreated cotton fibres was in



Cotton fibre Nanofibrils

the range of 500 nm after 30 passes, while a diameter of ~ 100 could be achieved within 15 passes due to pre-treatments. The process results in superior quality nano-fibrils from the non-spinnable cotton fibres.

Mango packaging: Packaging of mango with inner lining of CFB boxes (on all sides of box except top side with flexible film) reduced the weight loss of mangoes kept at room temperature by 50% during ripening. The storage life of sapota and aonla could be extended to 3 weeks at 10°C and 12°C, respectively, by MA packing in selectively permeable film, PD-961. Matured green guava fruits could be kept in unripe green condition for one week at room temperature and three weeks at 12°C by exposing them to 500 ppb 1 MCP (methylcyclopropene).

The semi-ripe (40–50%) Totapuri mango fruits with an acidity of 0.8–1.0% were found to be ideal for preservation by hurdle process. Passion fruit RTS beverage with alternate sweetener (sucralose) was comparable to that of RTS with normal sugar in taste. Osmotic pre-treatment before freezing was effective in improving the texture, yield and quality of dehydro-frozen mango (cv. Alphonso and Totapuri) slices. The threshold level of moisture content in osmotically dehydrated slices of papaya and pineapple was found to be 14–15 and 13–14%, respectively, to prevent browning and to have better storage life and quality retention.

Enhancing shelf-life of fruits: Shading the canopy from three sides enhanced fruit retention by 50%, reduces sunburning and fruit cracking by almost 40% than the open tree canopy in litchi. Litchi fruits first pre-cooled and then packed in perforated polythene bags (200-guage) lined with litchi leaf kept better up to four days at ambient temperature.The sprays of aqueous lac formulations on pomegranate cultivar Bhagawa during fruit development stage increased shelf-life of fruits up to 17 days over the control.

In apple**,** early variety Mollies Delicious has minimum shelf-life and its quality gets deteriorated within two weeks of harvesting. Trials were taken to increase the shelf-life of apple fruits of variety Mollies Delicious by treating with different concentrations of *Aloe vera* gel and shrink wrapping with different sizes of semi-permeable films. The fruits coated/treated with 50% concentration of *Aloe vera* gel and shrink wrapped in 25 µ film stored at low temperature (5 ± 2°C) extended storage life up to 68 days.

Improved shelf-life of flowers: The shelf-life extension of nine days was achieved in *Jasminum sambac* flowers by storage at 6°C packed in PE 100-gauge over control (two days at RT). Pre-transit solution (aluminium sulphate @ 300 ppm) in rose, pre-storage

pulsing solutions in gladiolus (20% sucrose+ 300 ppm aluminium sulphate + 50 ppm GA_3), holding solutions (2% sucrose + 45 ppm amino-oxy-acetic acid + 90 ppm Alar + 100 ppm Triton + 1 ppm GA_3 + 0.2 ppm, Kinetin), in carnation (2% sucrose + 300 ppm tartaric acid), in gerbera (2% sucrose + 100 ppm, aluminium sulphate), and in daffodil cv. Trumpet and lily cv. Cilesta (2% sucrose + 100 ppm 8-HQC + 150 ppm GA_3) extended the vase-life of flowers significantly.

In *Cymbidium* hybrids, among four harvesting stages, vase-life was highest in 75% open stage and treatment with $CaCl_2$ (1,000 ppm) for 15 mins. was best impregnating chemicals for Cymbidiums. In opening of tight bud of *Cymbidium* hybrid PCMV, treatment with 4% sugar + 200 ppm salicylic acid gave highest (75%) fully opened flowers with maximum vase-life (45 days).

Processing of safed musli: The proper stage of harvesting and peeling of safed musli (*Chlorophytum borivilianum*) was standardized. The early stage of harvesting [90–120 days after planting (DAP)] is not suitable for peeling as it is difficult and also time consuming. Minimum peeling time is taken when harvesting is done between 120 and 165 DAP. It is further revealed through anatomical studies that during 90–105 DAP epidermis is single layered with tight adherence with cortex tissues which makes the peeling of root difficult. At later stages (beyond 165 DAP), peeling is difficult due to lignification of epidermis and phelloderm layers.

Modified atmosphere packaging of meat emulsion: Storage of meat emulsion to make homemade convenience products under aerobic condition is not possible without affecting its quality. Effective storage of ground meat under modified atmospheric packaging (MAP) (70% O_2, 20% CO_2 and 10% N_2) using polyamide/polyethylene co-extruded films is possible up to 15 days at –1°C. MAP stabilizes the bright red colour of ground buffalo meat and reduces the lipid oxidation.

Sheep: Nugget, salami, sausage and kofta meat products of sheep meat were prepared and evaluated for consumer acceptability. In addition, new meat products like mutton soup, mutton pickle and enrobed eggs from meat of sheep were developed.

Fibre quality: In biotechnological studies, to avoid adulteration of quality fibre like pashmina with wool, species-specific PCR primers were developed for identification of fibre of different animal species.

Carpet from magra wool: Magra sheep produce excellent quality carpet wool. The carpet produced has low abrasion resistance due to excess amount of medullated fibre. A process was optimized to improve the abrasion resistance, for which the wool is blended with 10% nylon fibre. Improved carpet realizes 20% higher price than that of conventional carpet.

Release of area-specific mineral mixture technology: The area-specific mineral mixture was formulated on the basis of micronutrient status in soil, water, feed and fodder and animals of different livestock species in South-Western Semiarid, Central and Eastern Plain zones covering 30 districts of Uttar Pradesh. The use of the mineral mixture resulted in significant improvement in the fertility as well as productivity of different livestock species under field conditions.

Success story

Development of on-line system for monitoring aflatoxins M1 in milk

SIB-ESA developed at NDRI is working on-line with novel features like working under natural milk conditions with minimal pre-treatment, reproducible, simplified procedure, exhibited significant correlation with ELISA at Codex MRL Limit, i.e.0.5 ppb, and the developed assay (Patent Reg#3064/DEL/2010) can contribute immensely in dairy industry for routine monitoring of milk for aflatoxin M1 at collection point, chilling centre, manufacturing unit and R & D institutions. SIB-ESA is working on functionalized sensor disks and storage stability of sensor disks was up to 40 days. Spores on microfibre sensor disks were immobilized by incubating for 3.30 hr ± 30 min. SIB-ESA is performing well with these sensor disks. Indicator spores were also immobilized in small test tubes and chromogenic assay found to be working within three hours. The storage stability of spores in small test tubes was up to two months.

Livelihood from lac production

Lac production and crop protection technology on *Butea monosperma* (*palas), Schleichera oleosa (kusum)* and *Ziziphus mauritiana* (*ber)* were disseminated and adopted successfully on large-scale in several disadvantaged districts namely, Bastar, Dantewara, Kanker, Narayanpur in Chattisgarh; Dumka, Jamtara in Jharkhand; Gondia, Garhchiroli, Yawatmal in Maharashtra, Mayurbhanj, Keojhar in Odisha; West Medinipur, Purulia and Bankura districts of West Bengal. Besides these, some other districts include Vishakhapatnam (Andhra Pradesh), Korba, Bilaspur, Raipur, Durg, Jashpur, Raigarh (Chhattisgarh), Betul, Seoni, Sahdol (Madhya Pradesh), Sundergarh (Odisha) and Allahabad (Uttar Pradesh), etc.

Value-added products

Dried instant mushroom soup-mix: A dried instant mushroom soup-mix was developed which is highly acceptable, convenient and appetizing processed product. The drying of milky mushroom slices was carried at 50–55°C in a partially ventilated oven. Dried mushroom was grounded to make powder of uniform particle size. The initial moisture content was around 90% which on drying reduced to approximately 5% that gave the resultant powder a good consistency and free flowing property. Dry soup-mix was prepared by using 20–22% mushroom powder with other common ingredients of dried vegetables and spices in stock to achieve thick consistency with good appearance and taste after reconstitution.

***Makhana kheer* mix:** A ready *makhana kheer* mix mainly consisting of ground *makhana,* milk powder, sugar, commonly available binder and natural flavouring agents was developed. The *kheer* is prepared by adding requisite amount of water in the developed mix and stirring. The shelf-life of the product is more than six months. Its proximate composition is protein 11.5%, carbohydrate 64.7%, fat 7.6%, moisture 13.9%, and minerals (phosphorus, iron, calcium) 2.2%. Quality of protein is comparable with that of fish and is beneficial in getting immediate energy, besides having medicinal values of *makhana*.

Jute-glass hybrid fabric: A jute-glass hybrid fabric was developed for application as reinforcement in composites. These fabrics are woven with different structures and are modified by a physical method involving heat treatment. The weight of the hybrid fabrics with jute content of 40–60% was observed in the range of 450–750 g/m^2. It requires less resin for wetting and impregnation compared to jute fabrics. Fibre loading of 35–40 % of the composite can be achieved with this fabric by simple hand lay-up techniques. The resultant composites are superior in physical and mechanical properties to those based on either jute or jute-glass sandwich systems.

These fabrics can be used to mould various products such as fittings for automobiles, railway coaches and machinery. These are also suitable for moulding storage bins, chairs/benches, doors, wash basins, corrugated sheets etc. replacing metal, GRP, wood/plywood. Products are lighter than those made from metal or GRP.

Eco-friendly *holi* powder: A simple process for production of safe, low-cost *holi* powder from cassava (tapioca) flour was developed. Cassava tubers are peeled, sliced and dried to produce cassava chips. Cassava flour is made by grinding the chips in a grinder or hammer mill. The flour is uniformly mixed with Fruits Products Order 1955 (FPO 1955) approved food colour solution (10%) in water in 1:1 ratio. The high starch content (94–95%) of cassava or tapioca flour helps the colour to be uniformly distributed within the base material. After drying in the sun for three hours, the dried product is again ground in a hammer mill and sieved to less than 250 micron size.

The *holi* powder stored at room temperature inside polypropylene bags retained colour fastness for 45 days. Sensory evaluation with regard to colour brightness, stickiness of the powder and overall acceptability was satisfactory for fresh as well stored *holi* powder. Five safe *holi* colours (green, blue, red, yellow and chocolate) were developed with acceptable particle size (53–250 micron), stickiness and colour fastness remaining till 45 days. Production cost is ₹ 100/kg.

Synthesis of hydrogel from *Karaya* and *Acacia* gums: Hydrogels, polymeric networks that absorb large quantities of water, were synthesized from gum *karaya (Sterculia urens)* using grafted co-polymer of modified gum *karaya* with three acrylic acid substituents as cross linking agent. The equilibrium swelling of the *karaya* gum hydrogels prepared using these agents varied between 1,190 and 1,600. The morphologies of gum *karaya* and its hydrogel were analyzed by SEM images. The gum *karaya* showed a tight structure while its hydrogel had a porous structure due to the formation of interpenetrating networks. Hydrogels prepared from the grafted copolymer of gum *Acacia* with acrylamide and methacrylate using cross linking agent showed much higher equilibrium swelling, 3,200 and 4,100%, respectively, after 24 h at room temperature.

Lac dye: Long-term (52 weeks) dietary toxicity study of food grade lac dye in rats, following Organization for Economic Co-operation and Development (OECD) guidelines for testing of chemicals for chronic toxicity, guideline no. 452 was carried out at IITR, Lucknow. It was concluded that long-term repeated dietary exposure to test food grade lac dye up to 2% diet or 1,000 mg/kg/d dose (limit test dose) is not likely to produce any toxic effects and may be treated as no adverse effect level under the test conditions was observed. This has paved the way for declaring lac dye as food additive.

Shellac-based surface coating compositions: Compositions based on shellac-novolac and shellac-epoxidised novolac blends in combination with melamine formaldehyde (MF) resin were developed. They were found suitable, especially for coating metal surfaces providing high gloss, good scratch hardness and impact resistance. Baking of films improved the properties tremendously. It has been found that 30–50% of shellac can be replaced with rosin, in the varnish formulation based on lac-synthetic resin, developed earlier for wooden surfaces. This leads to cost reduction with minor impact on the properties.

Mango wine: It was developed from three mango varieties, viz. Dashehari, Langra and Chausa, using *Saccharomyces cerevisiae*. The product had parameter profile of 8.8°Brix TSS, 0.58% acidity, 0.97 mg/100 ml ascorbic acid, 0.05% tannins, 1.04% reducing sugar, 1.82% total sugar and 10.4% alcohol. Similarly, bael wine was developed using *Saccharomyces cerevisiae* with 14.8°Brix TSS, 0.87% acidity, 2.35 mg/100 ml ascorbic acid, 0.36% tannins, 5.82% reducing sugar, 6.51% total sugar and 8.6% alcohol. A partially fermented (4% alcohol), mildly spiced, anti-oxidant rich beverage having distinct flavour and taste was developed from raw mango fruits using *Saccharomyces cerevisiae.*

Colour retention in green chillies: Hot water blanching of green chillies at 100°C for 11 min. with additives treatments (0.75% potassium metabisulphide, 0.125% $NaHCO_3$ and 0.1% MgO) inactivated the catalase and peroxidase enzymes completely with better ascorbic acid retention (59.96 mg/100 g) as compared to blanched chillies (20.95 mg/100 g) without additive. Dehydration of blanched chillies at 50°C retained the maximum green colour and ascorbic acid content as compared to drying at 60°C and 70°C. Rehydration

of dried green chilli flakes at 100°C for 45 sec. resulted in better retention of texture, vitamin C (26.47 mg/ 100 g), capsaicin (0.36%) and green colour.

Potato-banana flour: Blending of potato flour with banana flour in equal-quantity enhanced nutrients value (free amino acid, soluble protein, total phenols, carotenoids, starch and glucose) in the resultant mixture. A ready-to-eat extruded snack food product was developed from cassava rice flour blends which had high expansion ratio and good textural quality. Cassava starch-based biodegradable film was developed with antimicrobial activity by adding garlic, clove or cinnamon oil in starch-glycerol-gum composites.

Antioxidant potential of fruit *dahi*: *Dahi* was prepared by using NCDC 167 and NCDC 261 in the ratio of 1:1, incorporated with different levels of strawberry pulp/mango pulp (6–12% level). Based on sensory evaluation, *dahi* incorporated with 8% strawberry pulp (corresponding to 17.8° Brix) was adjudged as best for overall acceptability. Similarly, mango *dahi* showed optimum sensory quality at 8% mango pulp (20.1^0 Brix) fortification. The products were evaluated for their compositional parameters, physico-chemical and textural properties. The total solids for strawberry *dahi* and mango *dahi* corresponded to 18.42 and 18.39 %, *p*H 4.44 and 4.50, while firmness as 0.53 and 0.58 N respectively. The antioxidant activity measured by FRAP method was 82.75, 173.94 and 255.5µg Trolox equivalent/g for control, mango and strawberry fortified *dahi* respectively. High correlation values were observed between different methods of antioxidant capacity and between total phenolic content for different fruit *dahi* preparations. Further, during storage in refrigerator for three weeks, there was no significant difference in antioxidant potential of mango and strawberry fortified *dahi*.

Fermented butter milk drinks: *Dahi* was blended with cucumber juice and water (1:3) and to enhance the taste and aroma, salt @ 0.7% and steam distillate of ginger @ 6% were added to the drink. The product packed in glass bottles kept well for 15 days under refrigerated storage. *Dahi*, carrot extract and water were blended in a proportion of 1:1:2 and to this salt at a level of 0.6% was added. Adopting the same procedure, tomato buttermilk drink was prepared. *Dahi* (25 g) was blended with clarified mango juice (45 g), sugar (12%) and water (30 ml) to obtain a mango buttermilk drink. Guava extract with 1.5% total solids was blended with *dahi* and water (1:1:2) and salt (0.6%). Thermization and carbonation of buttermilk drinks helped to extend the shelf-life of the buttermilk drinks. These products were well accepted during sensory evaluation.

Cheese-based functional food: Cheese-based health promoting food was developed using oats. No significant difference was observed in cheese made by using three emulsifying salts of tri-sodium citrate, sodium hexametaphosphate and di-potassium hydrogen orthophosphate. The crude fibre and ß-glucan were 3.09% and 1.104%, respectively, on dry matter basis. All the samples showed an increase in *p*H and tyrosine during storage at room temperature and cold store. Free fatty acid content increased from 0.209% to 0.212% in tub and 0.257% in pouch packed samples of processed cheese with oats during storage in cold store. Yeast and mould counts showed an increase in all the samples irrespective of packaging materials and temperature during storage. Processed cheese with oats degraded chemically as well as microbiologically faster than control processed cheese. Tub was found more suitable than pouch packaging. The average cost of production of processed cheese with oats is ₹ 130/ kg.

Products of camel milk: Chocolate *barfi*, *peda*, skim milk powder and rasogolla were prepared from camel milk. *Chhana* made from camel milk plus cow milk (1:1 ratio) and camel milk plus buffalo milk (1:1; 1.5:1 ratios) showed good binding and tested good and had good acceptability as rasogolla.

Meat products: *Cured and smoked mutton products*. Cured and smoked products as restructured mutton blocks and mutton ham were developed to meet the consumer demand.

Emulsion products from spent hen meat. Value-added products such as emulsion stuffed capsicum, emulsion stuffed samosa, emulsion bonda and emulsion omelette etc. from spent hen meat could be produced as value-added products.

Freeze dried fish balls: They were prepared from the mince of snapper (*P.multidens*) by incorporating curry leaf, mint, turmeric, ginger, garlic and pepper. A combination of spices used in fish balls had a synergistic effect against oxidation and helped in enhancing the taste. Shelf-life of tapioca and fish curry was increased to three months at ambient storage when packed and processed as twin packs in high impact polypropylene (HIPP) thermoformed containers. These containers were further packed in three layered see-through retortable to maintain the sterility. The shelf-life of vacuum packed yellow fin tuna chunks during storage at 1–2°C in ethyl vinyl alcohol (EVOH) extended under high pressure processing at 200MPa when compared to untreated samples.

Smoked and canned freshwater catfish: Freshwater catfish *Wallago attu* was smoked and canned in oil in tin-free steel (TFS) cans. The meat texture of freshwater catfish is generally soft and to make it firm and non-sticky it was given the smoke treatment. The smoke treatment improved texture, appearance, odour and flavour of canned freshwater catfish. The one-hour-smoked samples gave more attractive golden brown colour and appearance with good odour flavour than two-hour-smoked samples. Nine-month shelf-life studies revealed that products remained in good condition during this period; and one-hour-smoked samples were better in sensory characteristics than two hour treated and control samples.