10. Post-harvest Management and Value-addition

An essential component of the agriculture in achieving food security for all is preserving, processing and value-adding produce in the post-harvest chain. Huge losses occur of the produce in the post-production systems; estimated to range from around 4% for foodgrains to 18% for fruits and vegetables. The total monetary value of these losses as on 2014 price level was ₹ 98,000 crore per annum. Value-addition and preservation in post-harvest chain would help making greater and healthier food choices for the consumers throughout the year.

Cottage-scale pilot plant for probiotic soy-cheese spread and soy-milk powder: Probiotic soy-cheese spread was developed using starter cultures prepared on the sterilized tofu- whey culture medium. Different ingredients (cow milk, sucrose and okara) were added to soymilk as substrate for growing probiotic lactic acid bacteria, and coagulation process was optimized.

A cottage- scale pilot- plant with a capacity of 10 kg per batch for preparation of probiotic soy-cheese spread has been developed. Fermented soymilk with appropriate doses of probiotic bacteria was spray-dried as well as freeze-dried to obtain probiotic soymilk powder; at 4°C, all the samples were stable during 6 months of storage with a viable cell count of 10^7 - 10^8 CFU/g. Probiotic soymilk powder exhibited antioxidant and antimicrobial properties and tolerance to bile and acid.

(a) Cottage-scale pilot plant for preparation of probiotic soy-cheese spread; (b) Probiotic soy-cheese spread; (c) Probiotic soy-milk powder

Hybrid dryer for pigeonpea *dal:* A solar biomass hot- air dryer was developed for drying 350-kg soaked pigeon- pea (whole). The dryer unit is covered with UV-stabilized solarization sheet for absorption of solar radiation during the day time. External heating arrangement for operating during night and in cloudy weather conditions has been provided using two downdraft inverted gasifier stoves and conduction tubes placed in the plenum chamber. Dehydration chamber has six partitioned double tray racks. The plenum chamber is equipped with fans and blower for air circulation and uniform heat transfer. During testing, temperature in solar tunnel area was recorded as 70±10 °C and 50±10°C was at the plenum chamber while ambient temperature was 34±2°C. Approximate cost of the unit is ₹ 1.20 lakh. This unit will be very useful to milling industry.

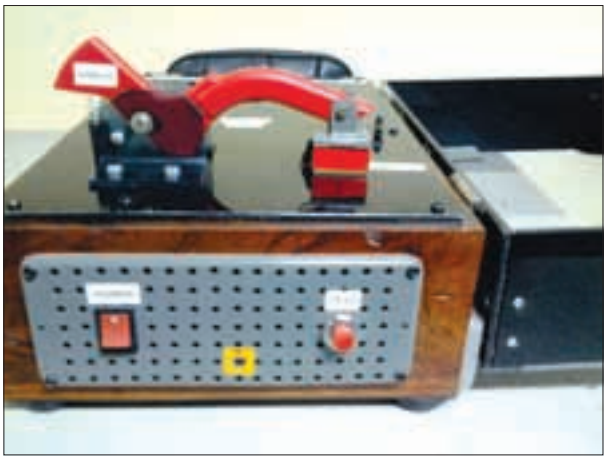
Hybrid dryer for pigeonpea

Heat treatment and ripening chamber for banana: To enhance the shelf-life of banana and for product safety, a set of equipment for post-harvest treatment of banana has been developed. This includes a hot-water treatment chamber and a collapsible ripening chamber. Hot- water treatment at 45°C for 45 min in a chamber of 20 kg per batch capacity retarded fungal growth and increased shelf-life of bananas by five days. The collapsible ripening chamber of one-tonne capacity resulted in uniform ripening of bananas. Temperature in the ranges of 15 to 17°C, relative humidity in the range of 85-90% and pre-determined ethylene concentration can be maintained in the chamber with domestic air-conditioner,

Collapsible ripening chamber for banana and other fruits

humidifier and ethylene generator, respectively. Five days were required to fully ripen banana at 17°C and 90% RH. Bananas ripened using this technique had two days longer shelf life than those ripened using traditional methods.

Testing electrical insulation of technical textiles: Technical textiles have come up worldwide in a big way. Measurement of electrical insulation properties of the fabric is essential especially when that fabric is to be used in the electrical field. An instrument has been designed and developed to measure electrical insulation of jute and allied fibre- based technical textiles. The digital instrument measures resistance in terms of Mohm/Gohm in the transverse direction of textile material up to 2-cm thickness. The measurement shows 99.6% accuracy. A safety measure has also been incorporated as the instrument works at high voltage and not in the open condition. Repeatability of the measurement was found good with deviation between minimum and maximum values insignificant at 1% confidence level in a sample of 30 measurements. This instrument is user friendly, is of low cost, is precise and easy to calibrate. It is useful for assessing suitability of fabric for electrical insulating products like gloves, jackets, floor covering etc.



Instrument for testing electrical insulation of jute and allied fibre-based technical textiles

Electronic colour meter for jute and mesta fibres: Following two types of colour measurement instruments for jute have been developed.

A very low-cost handy-type instrument: This uses indications for three major colour ranges of the fibre sample. Only 3 LEDs have been used for the indication of the colour range. Its main features are as follows.

- It is an automatic type and works on Light Reflectance technique.
- No expertise is required to operate it.
- It is a very low-cost device.
- It is portable and can work with rechargeable cells/solar cells/primary cell.

Electronic meters for jute and mesta fibres

A laboratory type colour meter for quantitative measurement: This has a digital 7-segment display, indicating colour properties of the fibre. Its main features are as follows.

- It is an automatic type and would work on Light Reflectance and Specular reflectance methods.
- The values of colour in terms of whiteness and lustre are displayed digitally.
- No expertise is required to operate the instrument.
- It can work both on AC 230V, 50Hz supply and from battery supply.
- Computer interface is present and can be used for stored data transfer in the computer.

Production of nano-cellulose on pilot scale: The process protocol for large-scale production of nano-cellulose from cotton-linters was optimized in Nano-cellulose Pilot Plant at Mumbai. The final product dimension was less than 100 nm with a consistency of 2% and the product can be produced both in a slurry form and in a powder form. This product can be a potential candidate for use as reinforcing agent in polymeric composites, concretes, natural rubber composites; as rheology modifier in paints; and as a carrier for pesticides and micronutrients.

Nano-cellulose production process
(*inset*: AFM image of nano-cellulose)

Biosynthesis of aleuritic acid in Indian lac insect: Aleuritic acid is one of the widely used starting materials for producing musk-odour compounds at perfumery industry. Its natural source is a lac resin from which it is isolated by alkaline hydrolysis. Biosynthesis of aleuritic acid in Indian lac insect has been understood based on the fatty acid profiling, enzymatic analysis and inhibitor studies. According to this, four enzymes (fatty acid desaturase (FAD), epoxygenase, epoxide hydrolase and monooxygenase) are involved in the pathway; using hexadecanoic acid as the starting material. The hydroxylation at 9^{th} 10^{th} and 16^{th} position is achieved through a four step biochemical process. This is the first report regarding biosynthetic pathway of aleuritic acid.

Lac mud utilization in vegetable and flower production: Lac mud is a waste of lac- processing industry. Analysis of lac-mud revealed higher content of

organic carbon (23.3%) and organic matter (40.2%). It also contains 0.65% N, 0.31% P_2O_5 and 0.12% K_2O. Sulphur, copper, zinc, iron, boron and molybdenum content in lac mud was also found quite high. Substitution of 25% of the recommended nitrogen through lac mud, 25% through vermin-compost and 50% through chemical source gave 36, 23 and 16% higher fruit yield in brinjal and tomato, and fresh leaf yield of spinach, respectively, compared with application of only chemical fertilizers. Application of fortified lac mud (0.2% N + 0.2% P_2O_5 + 0.2% K_2O) was found to be a better option as substitute for other organic manures for higher flower yield of rose and chrysanthemum.

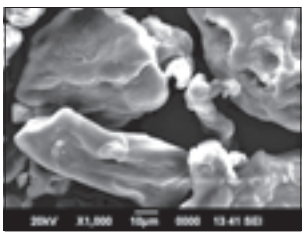
Carboxymethyl derivative of guar gum: India is the largest producer of guar gum in the world, and this gum is one of the best thickening, emulsifying and stabilizing agents. Guar gum hydrates well in aqueous solutions. Solution clarity, alcohol solubility and low thermal stability were the problems that led to the development of a number of chemically modified guar gums. Carboxymethyl derivative (anionic) of guar gum was synthesized, reacting guar gum with suitable reagents

Carboxymethyl derivative of guar gum

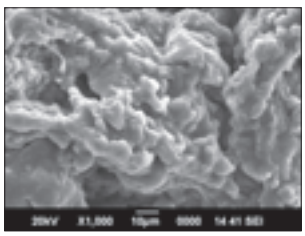
Solution clarity of carboxymethyl derivative of guar

using semi dry and non-aqueous method. The key physico-chemical parameters such as viscosity, time of hydration and degree of substitution (Ds) of the synthesized derivative were estimated for confirmation of derivatization. The viscosity and solution clarity of aqueous solution of carboxymethyl guar increased with higher Ds of the derivative; it finds its application in fabric printing, oil well fracturing, mud drilling and industrial application and preparation as stabilizer, thickener and suspending agents.

Hydrogel from guar gum: Hydrogels have been synthesized using grafted co-polymer of modified gum with vinyl substituents. The optimization of reaction parameters for synthesis of hydrogel for concentration of monomer, cross linker and initiator has been completed. Guar gum shows a tight structure while its hydrogel is a porous structure due to interpenetrating network formation.



SEM image of guar gum



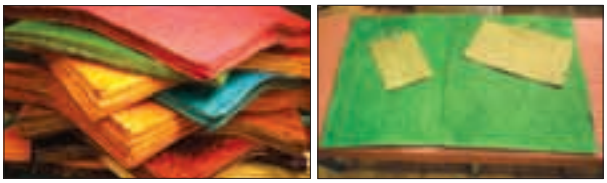
SEM image of guar gum based hydrogel

Nail polish formulations: Nail polishes are synthetic resin and pigment based and can reach stomach along with food materials while eating, during feeding children and due to nail-biting. A natural nail polish formulation (IINRG-NPL-05) has been developed based on the lac resin (a natural material). It gives very glossy, hard, smooth and durable finish on nails, and is quick drying and non-hazardous to health. It conforms to requirements of BIS standard (IS: 9245:1994).

Natural nail shine

Lignocellulosic fibres for pulp and paper: Removal of lignin from lignocellulosic raw materials requires pulping. This required many chemical treatments with caustic, sulphide, sulphate-based chemicals. These treatments result in huge effluent production. An eco-friendly process has been developed where bio-treatment of lignocellulosic fibres produces a raw material that requires very low chemicals, and pulping can be carried out at a lower temperature. Even production of effluents is minimum with this, and paper produced was with improved optical and physical properties.

The fibres are first treated with cellulase-xylanase combination, followed by laccase treatment and low chemical Alkaline Sulphite Anthroquinene Methanol (ASAM) pulping at 115°C for 3 hours. The pulp thus produced requires minimum of mechanical beating. The pulp is bleached by environment-friendly hydrogen peroxide bleaching process for whitening. The pulps thus produced are being utilized for making handmade papers of different arial density to produce drawing paper, carry-bag paper, visiting card and file- cover paper, crack paper and writing paper.



Lignocellulosic fibres raw material for pulp and paper

Eco-friendly printing of jute with natural dyes: Printing of designs on mordanted-bio-scoured-bleached jute-fabric was carried out by screen printing method using 40-mesh size. Curing of prints was done by steaming, followed by soaping and washing.

The printed jute-fabrics thus produced are of very high design sharpness and fastness properties like washing

Printed with natural dye extracted from annatto seeds

Printed with natural dyes extracted from roots of manjistha

and rubbing. The eco-friendly printed jute can be utilized for production of fashion-bags, home- textiles, and fashion- garments.

Design and development of jute- based decorative fabrics: Thirty designs suitable for jute with silk and jute with cotton union blended fabrics have been developed. Also ten jute-based decorative fabrics (₹ 120 to ₹ 170 per sq. m) with minimum jute content of 55% for light weight winter jackets, slippers, and some ladies outerwears were developed. Fancy jute covered yarn/mat stick-based ornamental fabrics have also been developed, which may be used for floor-mats and as different value-added products. Slippers and office bags have been developed from jute-based ornamental fabric and file folder and shopping bag have been developed from jute/ mat-stick fabric. In an effort for commercialization, one MOA has been signed with Miltex Eco-fibres, Coimbatore, Tamil Nadu. About 50 metres of jute/silk lightweight fabric was supplied to Miltex Eco-fibres; total revenue generated through this was ₹ 40,000.

Jute-based decorative fabrics

Flame-retardant finishing of jute textile: Nano ZnO can be easily synthesized by wet chemical methods such as alkaline hydrolysis of respective metallic salts at ambient conditions. Considering the ease of synthesis and yield, ZnO is selected as a suitable nano particle for jute textiles to impart flame-retardancy. Chemical synthesis of flame-retardant nano-particles was done by adding sodium carbonate 0.12 M solution slowly to 0.1 M of zinc nitrate hexa hydrate solution in ten minutes, followed by continuous stirring for 60 minutes using magnetic stirrer. After 60 minutes, zinc nitrate was converted into $Zn(OH)_2$. The nano $Zn(OH)_2$ solution was then dried at 90°C for 2 hours to remove water, followed by calcinations at 400°C for 2 hours. The yield of nano ZnO was 48%.

Indian pineapple leaf fibre (PALF) for apparels: Pineapple leaf fibres were extracted and softened by decortication and subsequent water-retting. Decorticated-cum-retted fibres have showed better physico-mechanical and surface appearance properties than the decorticated ones. The fibres developed by this method are fine (10.2 micron), soft (flexural rigidity, 3.2) and have excellent natural surface appearance. Whiteness and brightness indices of retted fibre are 60 and 41. Balanced coefficient of friction between fibre to fibre (44, 64), moderate strength (19g/tex) and low flexural rigidity indicates its spinnability for yarn formation in automated spinning system. Fine yarn (38 tex) can be spun in the silk spinning system and the property performance has been found suitable to make eco-sustainable novelty fabric. Yarn properties such as breaking tenacity (22.5), flexural rigidity (3.2), moisture absorbency (8.0) are found good for making apparel-quality fabric. Fabric was developed using cotton as warp yarn and pineapple leaf fibre as weft yarn in a handloom. High initial modulus of fabric indicates very good dimensional stability of the fabric. The abrasion resistance is notably high, showing weight loss value 3.35%, even after 3,700 cycles, indicating its high durability. Water-wicking property of PALF is almost similar to cotton, and high rate of absorbency of PALF shows its ability to absorb perspiration within a short time. Its crease recovery angle is nearly similar to that of commercial cotton. Thus, pineapple leaf, an agro-waste, can be successfully utilized for making green-fashion fabrics.

Decorticated and retted PALF

Electrospun fibre mat from cellulose acetate: A novel electrospinning process for production of nano-fibre mat from Cellulose Acetate (CA) has been developed by which nano fibre of diameter 100-220 nm could be produced. The optimized process parameters included 25 kV DC voltage, 15 cm distance between needle and collector and 0.03 ml per minute of polymer flow rate. This electrospun fibre mat can be used as matrix for the development of nanosensors.

Jute fibre reinforced polypropylene composite: DREF- friction spinning process was used for the preparation of jute reinforced polypropylene composite. Nine different Jute core polypropylene wrapped yarns were produced with varying core yarn twist level and jute: polypropylene proportion. The core spun yarns were converted into fabrics in both plain and twill weave and finally fabrics were converted into a total of 18 different composite

Jute polypropylene composite

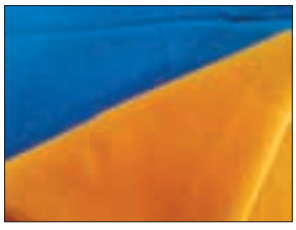
materials using compression molding process. It was found that with increase in jute reinforcement, the composite tensile strength either increased or remained constant. It was noticed that the plain weave structure had a little advantage over twill weave for this type of composite material. These types of composites can be used as an alternative to plastics, especially for high-strength applications.

Ginning of long-staple cotton on rotary-knife roller gin: Double roller (DR) ginning technology is widely used in India despite low ginning rate and there is limited scope for improvement in its productivity. The rotary-knife roller ginning technology is used in the USA and Turkey as a higher-capacity option in comparison with the double roller (DR) gin. It gives better fibre-spinning quality compared with saw ginning. Advanced rotary knife-roller ginning technology has not been practised in India because of higher fibre neps and seed cuts while

Rotary-knife roller gin

ginning Indian cotton. Hence, a commercial rotary knife-roller gin was evaluated and optimized for efficient ginning of Indian cotton. The efficient ginning was obtained at a roller speed in the range of 200-225 rpm, rotary-knife speed of 400-450 rpm, feeder roller speed of 18-20 rpm and at a pressure of 80 bar between the roller and the rotary-knife. The rotary-knife roller gin has a capacity of 425 kg lint per hour and is a higher-capacity option compared with DR gin, which has only 90 kg lint per hour. Hence, to increase profitability of ginning business and to ensure timely processing of cotton, rotary knife-roller gins can be used successfully.

Cotton-rich/bamboo viscose blended functional fabric: Yarns (30s Ne) from cotton, bamboo and their blends (65:35) were produced using compact ring spinning technology. They were woven into plain weave construction (GSM- 144, 82 ends × 72 picks per inch) on a sample loom. The fabrics were then subjected to scouring and bleaching through chemical and enzymatic methods. The enzymatically scoured cotton/bamboo blended sample gave better softness and whiteness (Index: 61) than alkali scoured samples (Index: 64). Subjective assessment showed that the cotton/bamboo viscose blended fabric has better softness compared to 100% cotton-fabric.



Cotton: Bamboo: viscose blended functional fabric

Functional and nutraceutical food products

Composite flour eggless cake: This contains 8.3-12 g protein, 19-22 g fat and 4.7-8.4 mg iron per 100 g and is made of banana with yoghurt, chia seeds, soy-milk, refined oil and composite flour; replacing egg, fat and refined flour, respectively. The composite flour; contains wheat (33%), malted fingermillet (41%), sprouted soy (8.5%) and sprouted amaranth (17.5%).

Composite flour eggless cake

Multigrain tortilla chips (Nachos): Baked multigrain tortilla chips have been made from a combination of corn, wheat, rice, sorghum (plain and nixtamalized) soybean, greengram (sprouted and unsprouted) and skim milk powder. Nixtamalized and sprouted chips had an overall acceptability of 8.6 on a 9-point hedonic scale. Nixtamalized and multigrain-based tortillas have significantly higher calcium content of 466 mg per 100g compared with the plain corn chips. Nixtamalized and sprouted multigrain tortillas make a tasty snack and are healthy and nutritive.

Nixtamalized and sprouted multi-grain tortillas

Antioxidant-rich pasta from vegetables and buckwheat: Capsicum incorporated pasta was developed using 18% groundnut meal and 82% refined wheat flour in food formulation with 27.3 mL per 100g capsicum juice as a liquid portion. The total protein, phenolic content and antioxidant activity of this pasta were 17.81%, 341.68 mg per 100g and 18.11%, respectively. The overall sensory acceptability was 8.53 on a scale of 10. Beet root incorporated pasta was also developed.

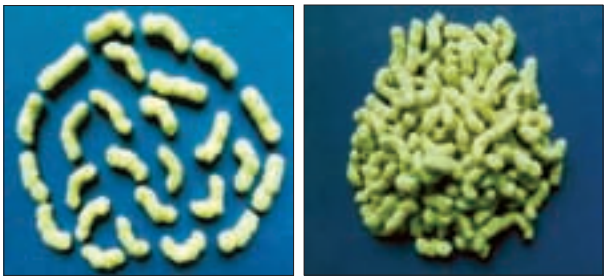
Protein and antioxidant-rich pasta with capsicum

Protein and antioxidant-rich pasta with beetroot

White ragi-malt-based designer food: In the backdrop of requirement of designer foods for targeted group of 2-5 years age, millet-malt-based food, which is 'Ready-to-Cook' and 'Complete One Meal Dish' has been developed. The process involves blending malted white

ragi flour at different levels with malted greengram flour (11.5%) and sugar (18.5%). Further, processes were optimized by incorporating skim milk powder (SMP), replacing greengram; whey protein hydrolyzate (WPH) up to 75% replacing SMP; and supplementation with honey and probiotics for enhancing consumer acceptability. Shelf-life of the developed product was 2 months.

Extruded snacks from broken walnut kernels: Nutritious extruded snacks from broken walnut kernels and rice have been developed with co-rotating twin-screw extruder. Storage studies revealed that the extrudates can be safely stored up to 3 months in LDPE bags under ambient conditions.



Extruded product from broken walnut kernel and broken rice

Pre-harvest field operations for improving post-harvest life of fruits: Bagging of litchi fruit bunches with white butter paper bags and non-woven polypropylene bags reduced sunburn and fruit cracking by about 30-35% and increased fruit weight by 6-16% over the control.

In litchi, *Bacillus subtilis* @ 1×10^8 cell/ml, potassium silicate @ 0.5%, chitosan @ 1%, Carbendazim @ 0.2% as post-harvest dip were effective in controlling fruit-rots up to 6^{th} day compared to 3 days in the control. Fruit dipping in chitosan (1%) + *B. subtilis*@1×10^8 CFU or Carbendazim (0.1%) maintained quality and increased shelf-life of fruits up to 18 days at freezing temperature.

Pre-harvest spray of GA_3 (100 ppm) + potassium sulphate (1%) significantly reduced fruit cracking (14%) and increased fruit weight by 15% in litchi cv. Shahi.

Extension of shelf-life: Treating the minimally processed pomegranate arils with salicylic acid, *Aloe vera* gel and ascorbic acid/citric acid extended shelf-life up to 19 days at 5°C.

Processing and value-added products: A processes for total utilization of commercially unmarketable pomegranate fruits (mature fruits with spots, slight cracking and over-sized) into juice, wine, pomegranate seed oil, organic mouth wash and bio-colour from rind was standardized. Litchi pulp could be preserved up to 10 months at 6±1°C with a treatment involving pasteurization and addition of 1500 ppm potassium meta-bisulfite. A probiotic drink having 5.7×10^8 CFU/ml *Lactobacillus* load, 4.8°B TSS, 0.61% acidity and 12.2 mg ascorbic acid/100 ml was developed from raw mango fruits through lactic acid fermentation. Similarly, a probiotic drink using mature unripe bael fruit having 6.4^0Brix TSS, 0.52% acidity, 0.7 mg/100 ml ascorbic acid and 312 mg/100 ml total phenolics was developed through lactic acid fermentation. A process for making ready-to-drink carbonated acid lime and Nagpur mandarin juices was developed and commercialized to an entrepreneur in Mohpa, Maharashtra.

Extending storage life of onion: During *rabi*, pre-harvest spray of 600 ppm IAA at 90 DAP and 400 ppm $CoCl_2$ at 105 DAP in Bhima Kiran, Bhima Shakti and Bhima Shweta varieties of onion reduced rotting and weight loss during storage.

Processing and value-addition: A combination of edible coating (pectin or PVA) and modified atmospheric packaging of minimally processed carrots extended its storage life upto 21 days at 8^0C without significant deterioration in quality. Lycopene enriched tomato soup and juice exhibited good retention of nutritional and sensory quality till 2 months of its storage in glass bottles under ambient conditions (28.72- 35.58^{0}C). In potato, microwave processing at 600 W for 2.5-3 minutes, produced potato chips with acceptable sensory scores (7.6 on 9 point hedonic scale) and low fat content (~3.57% vs 35.5% in commercial preparation). A fortification technique with whey protein concentrate for making enhanced protein (19.43%) starch noodles from sweet potato was perfected. For production of a low glycaemic flour *spaghetti* and *starch*, NUTRIOSE®, a commercial Resistant Starch source with a high dietary fiber content (85%), was observed an excellent additive to sweet potato flour and starch.

Coco-sap chiller: A device 'coco-sap chiller', which can easily be connected to spadix of coconut palm, and retains low temperature for longer duration while tapping the sap for collection of fresh hygienic coconut inflorescence sap (*Kalparasa*) was developed in partnership with a farmer. Quality evaluation revealed the superiority of the product over the traditional *neera*. When pasteurized and packed in plastic bottles with 0.1% Nisin, the product stored well with good keeping quality (15 days) both at ambient and refrigerated conditions. The technology was transferred to 12 firms in south India.

Value-added product of coconut oil cake: Virgin coconut oil cake (a byproduct in virgin coconut oil production) rich in proteins, phenolics and antioxidants was successfully utilized for sweet snacks and extruded value-added products production.

Milk

Detection of *E. coli* in milk: Two-stage test was developed for detection of *E. coli*. The developed test can be used in dairy industry for routine detection of *E. coli* in milk and milk products for regulatory compliance. The novel features of the test is rapid detection within 15.0 ± 1.15 h as against 3-5 days protocol in conventional method and selective inhibition of contaminants like *Salmonella, Shigella, Citrobacter, Enterobacter, Proteus, Serratia, Yersinia, Staphylococcus aureus, Bacillus cereus.*

Detection of oxytetracycline antibiotics residues in milk: A rapid and semi-quantitative lateral flow assay (LFA) was developed to screen oxytetracycline (OTC) antibiotics residues in milk samples. The assay was validated by spiking OTC to antibiotic free milk samples and results were accomplished within 5 min without the need of any equipment. The visual detection limit was 30 ppb. The developed LFA can be used as a rapid screening method at farm to fork level.

Extraction of antibiotics from food matrix: Imprinted polymers against oxytetracycline, cephalexin and cefquinome were prepared over the surface of iron magnetite and evaluated for extraction of antibiotics from food matrix. These polymers could extract 62 to 94% of the antibiotics from water, milk, honey and egg white.

Quality evaluation of dairy products: Machine vision system (MVS) was designed and developed and successfully evaluated for colour measurement of plain *burfi*. The developed system can be used for improving quality control and providing a highly useful color measuring tool for the food industry.

Technology of cheese dip: The technology for the manufacture of cheese dip was developed using sodium caseinate, WPC-70, Cheddar cheese and milk fat with the addition of unique combinations of stabilizer and emulsifiers and to enhance the palatability of cheese dip, four different spices were tried at different levels. The process developed for the manufacture of cheese dip has great industrial potential.

Value-addition: Processing techniques were standardized for Mozzarella cheese, Paneer, Gulab Jamun etc. From sheep milk.

Camel milk for treatment of autism in children: Camel milk consumption by 41 autism children as an adjunct to other form of treatment for 3 months resulted in improvement in 78% cases by having better scores on Autism Treatment Evaluation Sabel (ATES) scales.

Meat

Time temperature indicator: Total volatile basic nitrogen (TVBN) sensitive indicator sensor and on-package sticker type time temperature indicator was developed for monitoring meat quality and safety during storage conditions. A strip type indicator sensor based on bromophenol blue coated nitro cellulose membrane was developed, which when kept inside the packaged meat reacts with the TVBN released from the meat and changes colour from yellow to blue upon quality deterioration.

Shelf-life of pork products: Addition of *kordoi* (*Averrhoa carambola*) fruit juice and bamboo (*Bambusa polymorpha*) shoot extract significantly affected the instrumental colour values of the nuggets. Estimation of TBARS (thiobarbituric acid reactive substance) value, which indicates the oxidative stability of products, revealed that nuggets with *kordoi* fruit juice and bamboo shoot extract had significantly lower TBARS values on the day of processing compared to the control. Antioxidant components present in bamboo shoot extract and *kordoi* fruit juice significantly slowed the oxidation process of fat in pork nuggets during the storage period.

Poultry

***Sous-vide* processed chicken sausages:** *Sous vide* processing technology was developed, which is efficient in prolonging the shelf-life of chicken sausages to more than 90 days under refrigeration temperature (4 ± 1 °C) as compared to a shelf life of only 20 days wider aerobic processing.

Standardization of process for development of instant emu egg noodles: Process for development of instant egg noodles was standardized using emu eggs (60%) in combination with cereal flours, table salt and other seasonings. Emu egg noodles showed yield up to 60% with very good water absorption index and shelf-life of over 6 months at ambient temperature in air tight PET jar. The noodles contained moisture, protein, fat, ash and carbohydrate @ 8.3, 18.7, 14.6, 4.26 and 54.08%, respectively. The product was well accepted by the sensory panel members.

Thermal death time modeling of *Salmonella* Typhimurium using antimicrobials on dressed chicken: Decontamination study was carried out for thermal inactivation of *Salmonella* Typhimurium on dressed poultry carcasses. Acidified sodium chlorite (100, 200 and 300 ppm) or carvacrol (0.02, 0.04 and 0.06%) at 56, 60 and 64ºC was used to design a mathematical model to show the efficacy of these antimicrobials in combination with thermal treatment for effective inactivation of *Salmonella* Typhimurium on dressed chicken carcasses.

Wool and hair

Biophysical characterization of pig hairs: The thermal conductivity studies indicated that the mean thermal insulation and conductivity values of pig hair fibre was 0.068±0.004 m^2K/W (range 0.04 to 0.14) and 0.029±0.003 W/m/.K (range 0.026 and 0.031) respectively. Thermal conductivity values of pig hair fibre were comparable to values reported for wool, cow hair, elephant hair, horse and rabbit hair indicating that pig hair can find application in places where natural fibres are utilized for insulation. Electron microscopic analysis of the surface of pig hairs revealed presence of scales similar to those of other species.

❑