

11.

Post-harvest Management and Value-addition



Management of agricultural produce after harvest and value-addition to it for increasing the nutritive value as well as giving remunerative price are important for improving the living standards of farmers and for making farming sustainable. It helps in the reduction of post-harvest losses and utilization of by-products and create employment opportunities. A number of machines, hand tools, gadgets, structures for safe handling and processing of farm produce, process protocols for value-added products, novel products and technologies and success stories for enhancing farmers income have been developed and few of them have been commercialized. The summary of such developments are given in the following paragraphs.

Compact fruit grader: The fruits of oblong or round shape can be graded by their diameter only. Other dimensions do not affect the grading of fruits. The fruit grader has feeding mechanism and rotating disc for smooth grading with minimum damage to the fruit. The rotating disc is fixed at a specific inclination with four grading boards. The developed grader was evaluated for its performance by grading ber fruit (Umran variety) which are oblong in shape. About 90% of grading efficiency was observed when the machine was operated @ 16 rpm. This machine has the capacity of 303, 375, and 460 kg/h with grading efficiency of 90, 74 and 65%, respectively. The machine grades the fruits in four categories: < 25 mm, 25 to 30 mm, 30 to 35 mm and > 35 mm diameter. The machine is operated by 1 hp electric motor.



Compact fruit grader developed at CIPHET Ludhiana/Abohar

Electrospinning system: A funnel shaped collector was designed and fabricated for conversion of nano fibre into twisted yarn. This design will pave the way for the production of nano fibre based yarn in an electrospinning set-up.

Moringa leaf stripping and drying: Moringa leaves are a good source of nutrition. To separate leaves from the tree branches, a mechanical moringa leaf stripper was developed. At a roller speed of 400 rpm the stripper had 95% efficiency and 50 kg/h capacity. Mechanically stripped fresh moringa leaves were washed with sodium hypochlorite solution before processing in a polyhouse

dryer. It took 11 h for drying 300 kg fresh moringa leaves from an initial moisture content of 75% to a final moisture content of 5% (w.b).

Bael/wood apple pulper machine: The unit can break bael or wood-apple fruit, extract the pulp and separates broken shells, seeds and fiber. The capacity of the machine is 120 kg/h and the pulp recovery is about 95 to 97%. The unit was developed at CIPHET, Ludhiana.



Bael pulper

Apple seed extractor: One kg seed is recovered from 10 quintals of apple pomace, which is quite laborious and time consuming. To fill this technological gap, apple seed extractor was developed on the basis of different fruit parameters.

The mechanically separated seeds had high seed germination potential (of about 89.9%) compared to commercially separated seeds from apple pomace (of about 65.3%). The capacity of the machine is 100 kg fruits/h. The estimated cost of apple seed extractor is ₹ 25,000/unit.

Cabinet dryer for drying tomato: A cabinet dryer with a capacity of 15 kg/batch, with gravel bed heat storage system developed earlier was evaluated for drying tomato. Tomatoes cut into round pieces (5–6 mm thick) were uniformly loaded in the drying trays @ 10 kg/m and dried from an initial moisture content of 92% to a final moisture content of 6.5% (w.b.). At solar intensities ranging from 400 to 1,175 W/m, temperature in drying chamber raised in ranges of 40° to 63°C (an increase



Mechanical apple seed extractor





of about 4° to 19°C higher than the ambient). The gravel bed temperature could be raised from 37° to 53°C.

Doffing system and enclosure for double roller gin: Dust pollution is a major concern in Indian cotton ginneries. More than 90% fine particulate matters (PMs) present in a gin hall are from the ginning point of the DR gins. To circumvent this problem an automatic pala doffing system and an enclosure of the DR gins were designed, developed and evaluated to determine its efficiency in arresting the fine particles that emanate from the ginning point of the DR gins. Rexin-cotton has been found as the most suitable material for doffing of pala lint. It arrests around 80% of total dust generated from the ginning point of the DR gins.



DR Gin with doffing system

Optimization of shade net design: Suitability of bamboo framed shade net-houses of 35%, 50% and 75% shadings with 2.5, 3 and 3.5 m height were evaluated for cultivation of vegetables. Considering the marketable yield and quality, the shade net house of 35% shade net with 3 m height was found suitable for tomato, capsicum, spinach, cauliflower, broccoli and marigold compared with open field and 50 and 75% shade net houses.



Optimized shade net

Net house for insect protection: Evaluation of net-houses constructed using stabilized nylon nets of 25, 40, 50 and 60 mesh sizes, for insect dynamics, micro-climate and production of tomato, capsicum, cabbage, cauliflower and broccoli in semi-arid region revealed that net-house of 50 and 60 mesh with aperture size of 0.3 and 0.28 mm were suitable to prevent the entry of minute insects such as whitefly, aphid, thrips and hopper.



Insect proof net house

Process protocols for nutri-bar: The process protocols were developed for multi-nutrient/snack bars using various proportions of nutritionally and functionally rich base mix including flaked oats, puffed rice, germinated and flaked greengram and soybean, malted finger millet, milk powder, roasted peanuts crushed and papaya. Four types of bars containing

honey, jaggery and corn syrup in different proportions were analyzed for sensory, nutritional, functional and textural properties and compared with commercial bar as reference. Protein, ash, phenolic, flavonoid content and antioxidant activity of all formulated bars were found to be better than the commercial samples. Jaggery-based bar has the highest iron (5.44 mg/100 g) and phosphorus (214 mg/100 g) compared with the reference samples containing 1.14 mg/100 g iron and 119.3 mg/100 g phosphorus. Mouth-feel and flavor, the important attributes for bar acceptance, were also the strongest quality attribute of all the formulated bars. On similarity analysis, reference and jaggery-based bar was both described as “good” and rest other bars as “medium”. From sensory, nutritional, functional and textural analysis the jaggery based bar was found to be the best among all tested bars.

Packaging and transportation of custard apples:

A participatory study was carried out with tribal farmers who were involved in picking of custard apple and selling it in market at very low prices. Foam sheet



Utility of plastics in handling, packaging and transportation of custard apples

was found to be the best packaging material for custard apple fruits during transportation for long distance to avoid loss in mass of the fruits, reduction in hardness of the fruits and variation in colour.

High protein extruded snack foods: Soy fortified functional extruded products were developed using rice flour (20–25%), corn flour (20–25%), wheat flour (10–15%), DFSF(5–10%), fruit powder (3–5%), vegetable powder (3–5%), SPI (3–5%) and dairy whiteners (5–10%). Protein, fat, carbohydrate and energy contents of the products ranged from 18 to 21%, 2 to 3%, 60 to 65% and 345 to 360 kcal, respectively, making the supplement to fulfil protein requirement for school children and others. The panel liked the product very much in terms of its texture, color, crispiness, appearance and taste. School children of 10 to 18 years of age rated the product as ‘very much liked’.

Electrospraying technique: An electrospray nano-finishing process was developed to produce antibacterial effect on cotton textiles. Voltage (30 kV), distance (15 cm), flow rate (0.04 ml/min) and duration of the spraying (8 min) were optimized to enable spraying of commercial antibacterial chemical with nano thick coating. Fabric



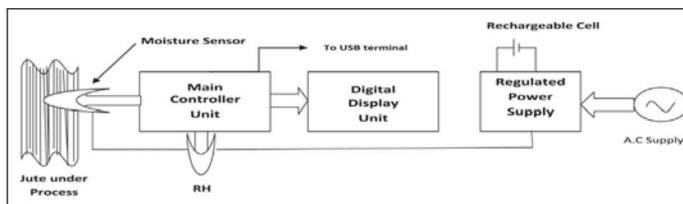
Electrospraying set-up fabricated at CIRCOT



electrosprayed for a duration of 8 min on both the sides exhibited good antibacterial activity against *Staphylococcus aureus* and *Klebsiella pneumoniae* cultures, with 99% inhibitions compared to that of conventional padding process and with 30% lower consumption of antibacterial chemical.

Regeneration of cottonseed oil: Large quantity of oil is utilized for frying in commercial food processing which takes place at elevated temperatures contaminating the oil with degradation of products of oil and food residues. Disposing this oil is a problem hence, an efficient process for regeneration of frying cottonseed oil for reuse or for other applications like biofuel preparations, was developed. The colour value of the regenerated oil was even better than the fresh oil while peroxide value was almost same to the fresh oil. Thus, the process is successful in regeneration of used frying oil.

Online moisture measurement system for jute processing system: This instrument can measure 3 parameters: Relative Humidity, Moisture Content and Moisture Regain while the jute is in processing. A special semiconductor type sensor was developed and fixed at the delivery of the carding machine which captures the input data and shows in the display. This sensor unit can also be placed at the input/output unit of any jute processing machinery to get those 3 parameters. A semiconductor type sensor which can inhale the moisture content at a very fast rate and produce the result instantly was used. One suitable micro controller was used to capture the input, compute the moisture content and moisture regain value and to display the same digitally. A separate sensor of semiconductor type was also provided with the instrument to measure the relative humidity and to display the same digitally in the same housing. Computer connectivity, was provided along with a suitable rechargeable battery so that the instrument can work independently for a suitable time span. The input sensor



Schematic diagram of online moisture measurement system

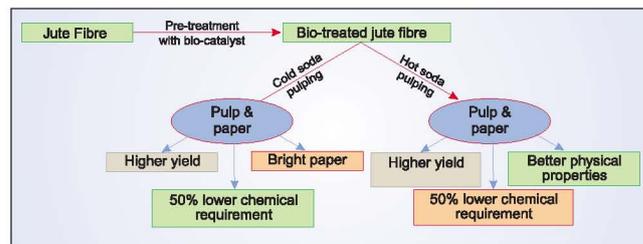


Online input sensor

Online moisture meter

was incorporated in a special type of attachment and is working satisfactorily. The readings of the instrument were calibrated with the dry oven test. The error was within $\pm 2\%$.

Making pulp and paper from lignocellulosic fibre: Cellulose and xylanase based enzyme and lignin degrading enzyme were used to study the effect of pre-treatment on optical and physical properties of fibers and to correlate them with the paper characteristics. Enzyme treated samples were beaten in a laboratory scale valley type beater to produce



Schematic diagram for paper formation using biotechnology

pulp of 40°SR freeness, and 60 GSM papers were produced. Biotreatment followed by peroxide made the paper bright. Sequential treatment of lacasse and cellulose-xylanase makes the fibres bright with some reduction in fiber tenacity. Fibers become finer after enzyme treatment. Folding properties of papers made from bio-treated and peroxide-treated fibers were poor.

Ber fruits for lac production: Exploitation of the potential fruit varieties of *ber* (*Ziziphus mauritiana*) for lac culture is a good proposition because in lac crop failure or non-use, these will yield marketable fruit. Thornless, Katha, Seb x Gola F₁, Jogia, Banarsi Karaka and Kaithali ber varieties had significantly higher lac yield than CAZRI Gola with yield advances of 42 to 69% over check. Illaichi, Kali, Katha, Jogia, Banarsi Karaka, Kaithali, Banarsi Pebandi and Mundia had significantly higher (17 to 84%) scraped lac yield compared to check CAZRI Gola. Based on biochemical and physiological parameters, Kaithali, Jogia, Seb x Gola (F₁), Banarasi Karka, Thornless, Kaitha and Banarasi Pebandi were found to have high potential for lac production.

Lac-based coatings: Pomegranate (*Punica granatum*), a commercially important fruit, suffers from significant post-harvest losses due to dehydration leading to weight loss and shrinkage on storage. Lac based



Pomegranate coated with lac-based formulation



Success story

Lac integrated farming system

Lac integrated farming system (LIFS) model was replicated at the field of Shri Prakash Sanga in Mangobandh village (Ranchi, Jharkhand) in an area of 1,500 m². This model is a hortilac system of *semialata* and papaya plants consisting of 27 paired rows of *semialata* having a distance of 2 m between each paired row with a row of papaya plants in between two paired rows of *semialata* alternately, 2,000 *semialata* and 140 papaya plants are accommodated in this model. The alternate rows of *semialata* where papaya has not been raised in between, integration of vegetables (tomato, brinjal, lady finger and chilli)



Hortilac model of Lac Integrated Farming System in farmer's field

was done, and 2,639 kg tomato, 670 kg brinjal, 90 kg chilli and 60 kg lady finger were harvested. As the *semialata* plants grew very healthy within six months, therefore in five rows, 20 kg of broodlac was inoculated on 270 plants in February for raising *jethwi* crop of *kusmi* strain in first year of plantation. Summer crop provided 68 kg brood lac and 4 kg rejected lac. Papaya yield was 30–40 kg fruits/plant after one year. So far the farmer has sold 13 quintals of papaya. Shri Sanga is earning year round income through diversified produce by adopting lac integrated farming system approach. His success and economic up-liftment has motivated other farmers also to adopt LIFS technology.

coatings were applied to determine the shelf-life extension of pomegranate fruits of cv. Bhagwa. Physiological loss in weight (PLW), shrinkage, glossiness, decay loss, TSS, acidity and TSS/acid ratio of the fruits and reduction in spoilage during post-harvest storage were observed. The shelf-life of the fruits was extended up to 16 days when stored at room temperatures. Coating, followed by cold storage extended the life up to 61 days. Enhancement in cosmetic appearance of the fruits, through increase in glossiness was an added advantage.

Policosanol: Lac wax, a by-product of lac industry, is used in varnishes and polishes as natural plasticizer. Lac wax on saponification yielded policosanol which is a mixture of long chain fatty alcohols. Plant growth

Success story

Enhancement of profit of lac manufacturer

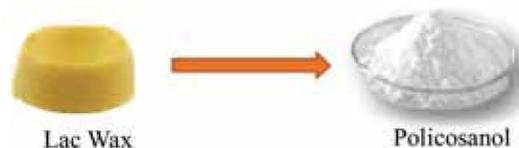
A young entrepreneur's keenness to learn and innovate coupled with his hard work has enabled him to set new landmarks in production of aleuritic acid, a value added product isolated from lac resin and mainly used in perfumery industry to develop musk-based perfumes. He was manufacturing only conventional products like seed lac and shellac. He came across improved method for manufacturing of aleuritic acid from lac resin published in the *News letter* of IINRG, Ranchi. He took training on manufacturing of aleuritic acid on pilot plant scale.

Initially, he established the manufacturing plant with one filter press using the new technique, which gave decent profits. He added two more filtering units and started manufacturing 3 tonnes of aleuritic acid, and earned a net profit of ₹ 24 lakh per annum. Besides consuming all the seed lac produced by his plant, he is also procuring seed lac from others to manufacture aleuritic acid for higher profits; his profit margin increased by more than 1.75 times by shifting from seed lac to manufacturing of aleuritic acid.



Breaking-off of lumps of pre-dried aleuritic acid

Drying of aleuritic acid in trays under controlled atmosphere



Lac Wax

Policosanol

promotion activity of lac policosanol is maximum at 0.1 ppm concentration in wheat seedlings.

Insecticide for integrated pest management in lac cultivation: Topical application of flubendiamide, an insecticide of new chemical class with a novel chemistry and new mode of action (targeting and disrupting the Ca²⁺ balance) under field condition against first and second instar larvae of lac insect showed its safety against *Kerria lacca* and significant reduction in the population of both key lepidopteran predators, *Eublemma amabilis* (Noctuidae) and *Pseudohypatopa pulverea* (Blastobasidae) predating on lac culture. The reduction in population due to different treatments of flubendiamide ranged from 87.9 to 100% in *E. amabilis* and 90.9 to 100% in *P. pulverea*. Laboratory evaluation of flubendiamide on eggs of *E. amabilis* showed 89.3 to 90.3% hatching inhibition response in different treatments. This insecticide can effectively be incorporated in IPM programme for the management of lepidopteran predators of lac insect.



Model retail outlet for chicken: In India, unorganized retail poultry meat shop account for 95% where sanitation is not maintained and chances of contamination during processing are high. A model chicken outlet (movable) was designed and developed.



Model retail outlet for chicken

This model retail outlet of size: 2.40 m × 0.6 m × 0.9 m is made up of SS304 stainless steel. The food safety parameters as per FSSAI were taken care and hence microbiological load of chicken samples was within the acceptable level. An entrepreneur in Belapur, Navi Mumbai has adopted this technology.

Banana: Shelf-life of pre climacteric banana with biochemicals was studied to know fruit ripening enzyme levels. Results indicated that the pectate lyase and pectin methylesterase activities were five times and 40-times higher in climacteric Grand Naine and in Poovan peel and pulp, respectively. Cellulase and Chlorophyllase activity were high climacteric (ripening stage 6) in Grand Naine and Poovan bananas than pre climacteric green bananas.

The varieties Poovan, Karpuravalli and Udhayam recorded 6 days green leaf shelf-life, which is comparable with wild species like Elavazhai and Phirima. Rasthali, Saba, Monthan and Kungsa wild registered 5 days shelf-life, while Pachanadan recorded the minimum shelf-life of 3 days.

Litchi: Modified atmospheric packaging (MAP) to enhance the shelf-life indicated that gaseous composition of 12–18% O₂ and 3–6% CO₂ had a shelf-life of 12–15 days under refrigerated condition, while at ambient condition shelf-life was only 5–6 days. A gaseous composition of O₂ and CO₂ in a ratio of 18:6 resulted in minimum browning (16%) and fruit decay (12%) as compared to natural gaseous composition in LDPE packaging.

Pre-cooling (10°C for 10 min) of litchi fruits treated with Carbendazim (250 ppm for 2 min) + chitosan (1% for 5 min) + citric acid (2% for 5 min) and packed in perforated polybag reduced fruit rots and physiological loss in weight (PLW) in storage at ambient condition. Fruits packed in perforated polybag and kept at 8°C + 80% RH had 47.6% fresh fruit up to 18th day of storage. The spray of Cropsil (40 ml/l) significantly reduced the cracking and sun-burn over the control, followed by Carbendazim (0.2%). The fruits sprayed with Carbendazim had acceptable shelf-

life. Litchi fruits pre-cooled, packed in LDP bag and kept in thermocol box containing 3 silica gel ice pads could maintain quality up to fourth day of storage with only 2.48% discarded fruit.

At harvesting, sun-burn caused 4.0–27% losses and there were 14% cracked fruits. However, there were 3–15% physically or mechanically damaged fruits during harvesting. The average loss at transport level in Delhi (wholesale) market was 8.9–17.2% and 10.6–23.3% loss when fruits had more than 50% browning. The average PLW was 7.1%. The improved packing methods in CFB boxes had reduced PLW by 2.58% and spoilage by 4.3%. At retail level, losses varied from 3.0 to 38.3% in Delhi market and 2.1–5.8% in Muzaffarpur market. Mean cumulative loss from harvesting to retail was due to mechanical loss (17.4%), browning (27.1%), PLW (7.07%) and pathological losses (17.9%).

Litchi pulp pasteurized and treated with 1,500 ppm KMS were acceptable in quality and colour up to 10 months when kept at low temperature (6±1°C). A technique for preparation of litchi nuts was standardized. Osmo-mechanical method of drying litchi flesh pre-treated with sucrose solution of 40° brix at a ratio of 1 : 2 fruit to solution, and 60°C as hot air drying resulted in highest overall acceptability of product with minimum hardness and drying time. Bagging of litchi bunches at 40 days after anthesis with white butter paper bags were the best to improve quality and colour of fruits.

Spices: Solar drying saved 29, 31 and 28% of total drying time for cinnamon, clove and black pepper, respectively. It required 10 h to dry to safe moisture content of 4–5% at 70°C in cabinet dryer. Cinnamaldehyde and eugenol were the major compounds contributing about 40.41 and 74.03% in cinnamon oil and clove oil, respectively.

Noni: Fruit coating with organic solvent *Aloe vera* gel (100%) improved the shelf-life of noni fruits as compared to untreated ones and retained higher content of carbohydrate (0.66 g/100 g), phenol (0.267 g/100 g) and protein (2.186 g/100g). Coating of harvested fruits with 5% Chitosan retained higher carbohydrate (1,103 mg/100g), protein (2,913.3 mg/100 g), phenol (172.27 mg/100 g) and antioxidant activity (60.58%) for extending the shelf-life.

Onion: Attempts were made to reduce the post-harvest losses by pre- and post-harvest applications. During *rabi* season, pre-harvest application of IAA (1.0 mM) and CoCl₂ (0.5%) at 105 DAP reduced post harvest losses. Pre-harvest application of CoCl₂ (0.4%) at 90 DAP reduced post-harvest losses during *kharif* season.

Arjuna herb based functional milk beverage: Extracts of *Terminalia arjuna* (TA), a medicinal plant recognized for its recuperative effect on heart ailments, possess an unpleasant flavour, bitter taste and abnormal red colour, which limits its use in functional food manufacture. Suitable matrix materials were tried to encapsulate the *Arjuna* herb for reducing undesirable effect on sensory quality of milk beverage. Functional milk beverages added with encapsulated herb (EHMB),





Extracting DNA from animal fat and milk fat

Consumers these days are concerned about their health and very selective in choice of food items. With a view to help the consumers, a method was developed to isolate DNA from animal fat and milk fat for PCR assay to detect any mixing of non-food items into food.

DNA was extracted from animal fat and milk fat and PCR assay performed using mitochondrial 12S rRNA, mitochondrial D loop (cow and buffalo specific) and mitochondrial 16S rRNA primers. The DNA isolated from milk fat and animal fat amplified the primers and the amplicons produced were as per the published results.

cocoa powder, sucrose and vanilla essence and stabilizer were optimized. In a consumer response study 96% respondents showed willingness to buy the product. The net production cost of the product was ₹ 85.32/kg. Functional milk beverage with better sensory quality, enhanced therapeutic value and reasonable cost could be prepared by addition of encapsulated *Arjuna* herb into chocolate added vanilla flavoured milk beverage.

Manufacture of *Aloe vera* supplemented probiotic lassi and probiotic ice cream: The technology for preparing *Aloe vera* supplemented probiotic lassi (APL) (up to 20%) was developed. The cost of production of APL was ₹ 12.26/200 ml. APL has a shelf-life of 9 days at 5–7°C. *Aloe vera* supplemented probiotic ice cream (ASPIC) was developed by using a probiotic culture, *Aloe vera* juice and whey protein concentrates.



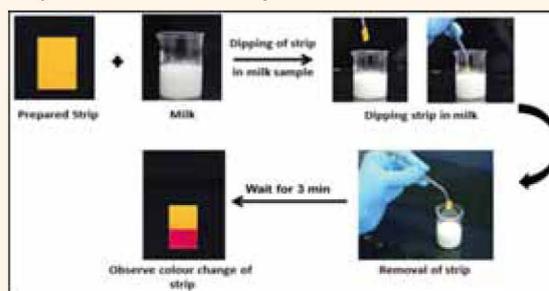
Studies revealed enhanced immunity as shown by higher macrophage count, lymphocyte count, phagocytic activity, lymphocyte proliferation index and IgA content in blood. Consumer survey showed high acceptability for both the products.

Determination of ACE inhibitory and antioxidant activities: *Lactobacilli acidophilus* and SARAS yogurt starter cultures were used for fermentation for evaluation of ACE inhibitory and antioxidant activities in the camel milk. The activities were significantly higher in all the fermented milk samples using *Lactobacilli acidophilus* culture. Comparative electrophoresis analysis of fermented camel, cattle and buffalo milk was done to evaluate profile of bioactive peptides. The presence of unique band in camel milk was observed which is missing in cattle and buffalo milk.

Success story

Quality assurance and clean milk production

Separate strips for detection of neutralizers, urea, glucose and hydrogen peroxide in milk were developed and validated. The test involves dipping the strip in milk samples followed by visualization of colour of the strip. The colour of the strip changes to deep red in milk containing neutralizers (immediately) and urea (after 2 min) while in pure milk samples, the strip retained its dark yellow colour in neutralizer



Steps in the detection of added urea in milk using strip

test or light red in urea test. For detection of glucose and hydrogen peroxide in milk, the test involves putting a drop of milk on the strip followed by visualization of change in colour of the strip. The colour changes to deep pink immediately in case of adulterated milk containing hydrogen peroxide while response time is 2–3 min in milk containing glucose. In negative samples, only light pink colour appears. The sensitivity of these strips was ascertained and is 0.04% for neutralizer, 0.06% for added urea, 0.03% for glucose and 0.02% for hydrogen peroxide. The tests are rapid and results are available within 5 min.

Detection of *Listeria monocytogenes* in milk: A “Two-stage bio-assay” was developed for detection of *L. monocytogenes*. The detection array could be completed in a single day as against 5–7 days using conventional method. The assay was nearly 10 times more economical — costing only ₹ 75/test.



Detection of *L. monocytogenes* in 25 ml of milk

Meat

Characterization of meat myoglobins: Buffalo and goat meat colour was characterized using two-dimensional electrophoresis and tandem mass



Success story

Meat on wheels

Newly designed “Meat on Wheels” vehicle for promotion and popularization of value-addition, meat processing and clean meat production among consumers and meat processors was launched at NRC on Meat during World Food Day celebration on 16 October 2014. The vehicle was designed under the project “Awareness on clean meat production and value addition” sanctioned from Directorate of Animal Husbandry, Government of Telangana under Rashtriya Krishi Vikas Yojana (RKVY) scheme 2013–2014.

Chicken meat bites

Process of poultry meat bites preparation was standardized using spent chicken meat along with seasonings (salt, sugar, phosphates, spices, condiments etc). Formulation containing 68.5% lean meat was most suitable in development of chicken meat bites based on different physico-chemical and sensory quality characteristics. This product has a shelf-life up to 21 days at refrigeration temperature.

spectrometry. Purified buffalo and goat myoglobin (Mb) samples revealed a molecular mass of 17,043.6 Daltons and 16,899.9 Daltons, respectively. The 2DE analysis of Mb's from buffalo and goat samples revealed 65 (crude Mb) and 6 (pure Mb) differentially expressed spots between them. Peptide mass fingerprinting (PMF) of Mb protein from 2DE gels confirmed the buffalo and goat Mb.

Goat products with healthy traits: Healthier chevon nuggets were developed through standardization of PUFA/SFA ratio in the range of recommended value via replacement of animal fat by vegetable oil. Higher proportion of vegetable oil in product significantly improved PUFA particularly omega-6 and decreased saturated and monounsaturated fatty acids. Replacement of 50% goat fat with combination of vegetable oils improved functional characteristics of chevon nuggets.

Thermal inactivation of *Salmonella* Typhimurium: Combined effect of antimicrobials with thermal treatment for inactivation of *Salmonella* Typhimurium using acidified sodium chlorite on dressed chicken carcass was very effective without affecting dressed chicken quality.

Safe broiler meat production: Dietary supplementation of curry leaves (*Murranya koenigii*) powder at 1.5 and 2.0% level improved oxidative control and meat palatability score of broiler chicken significantly without affecting production performance.

Wool and fibre

Fibres from pigs: Key by-product of pig farming is hair or bristle fibres obtained at the time of slaughter.

The average length of hair fibre varied from 56.8 mm in the Duroc to 127.1 mm in the Niang Megha breeds. The fineness of pig hair fibres ranged between 29.10 and 124.24 tex. The breaking tenacity of the fibres was similar and ranged between 11.9 and 17.0 cN/tex in different breeds of pigs. The extensibility of the



Hair or bristle fibres of different pig breeds (A, B, C and D)

fibres ranged between 21.1 and 39.5%, with an overall mean of 31.53%. The Young's modulus of the fibres obtained from Hampshire, Duroc, Ghungroo and Niang Megha breeds of pigs was 7.68 ± 0.08 , 4.25 ± 0.19 , 5.95 ± 0.17 and 7.70 ± 0.32 GPa, respectively. The SEM appearance of the pig hair fibre showing the arrangement of cuticles was similar to that of human hair.

Yak: At NRC on Yak, Dirang, for enhancing marketability and value addition, coarse hair of yaks were used for making hand bags and blended with jute fibre to prepare fine yarn in collaboration with NIRJAFT.

Fish

Succinyl chitosan based hydro-alcohol hand sanitizer: ICAR-CIFT optimized synthesis of an amphiphilic succinyl chitosan polymer, a semi-synthetic biopolymer with excellent biocompatibility and moisture retention capacity, and developed a hydro-alcohol hand sanitizer based on it. The hand sanitizer does not contain synthetic antibacterial compounds and is suitable for workers of fish processing industry.

Curcumin enriched hydrogel: A biocompatible and biodegradable hydrogel formulation composed of microencapsulated curcumin and hydrogel composite (chitosan derivative-fish collagen-poly ethylene glycol) was developed. Curcumin, anti-inflammatory substance having high hydrophobicity and rapid metabolism was encapsulated in succinyl chitosan micelles. The hydrogel significantly enhances collagen deposition and hydroxyproline content in wound tissue. The combined bioactivity of curcumin and composite hydrogel promotes tissue reconstruction process during wound healing.

□