

10. Post-harvest Management and Value-addition

Assessment of post-harvest losses: A comprehensive nation-wide quantitative assessment of harvest and post-harvest losses for 46 agricultural produces was carried out to estimate the extent of harvest and post-harvest losses. This assessment included five cereals, four pulses, six oilseeds, eight fruits, eight vegetables, sugarcane, four seed spices, three plantation crops, milk, meat, inland and marine fish, poultry meat and eggs. To assess these losses, data were collected through integrated stratified multistage survey design from 106 randomly selected districts of the country representing all targeted agricultural produces. Two blocks from each district and five villages from each block were randomly selected as second and third stage sampling units. Finally, ten farmers from each village were taken for the assessment. This assessment covered 14 out of 15 agro-climatic zones (Island region agro-climatic zone was not included). The data were collected through enquiry as well as actual observations. Estimates obtained through both procedures were combined by assigning appropriate weighing factors before arriving at final estimate of losses for a commodity. The operations considered for assessment of losses were harvesting, collection, threshing, grading/sorting, winnowing/cleaning, drying, packaging, transportation, and storage depending upon the commodity. The post-harvest losses in cereals, pulses, oilseeds, fruits, vegetables, spices, condiments (plantation crops) and livestock produce were found as 3.9–6.0, 4.3–6.1, 2.2–10.1, 5.8–18.0, 6.8–12.5, 3.6–6.8 and 0.6–6.9%, respectively. The post-harvest losses comprises essentially on-farm losses and those in transportation and storage in different marketing channels. These figures are preliminary estimates. Since there was no systematic study available, this study forms a milestone and can be considered as a bench-mark survey.

Peanut paneer: Peanut paneer is made by coagulating hot peanut milk with food grade coagulants. The paneer prepared from the whole kernel had moisture 62.1±1.8%, protein 13.6±0.5%, fat 19.2±1.5%, ash 1.9±0.2% and carbohydrate 3.2±0.1%. Fresh paneer had peroxide value of 6.24 meq O₂/kg fat, free fatty acids (% oleic acid) 2.83, lightness 81.6, total plate count 2 × 10² cfu/ml, yeast and mould 0.6 × 10² cfu/ml, hardness 1.04 N, cohesiveness 0.70 and springiness 0.92 mm. Peroxide value, free fatty acids, total plate count, yeast and mould count and hardness values increased during storage, whereas lightness and springiness decreased. Paneer samples packed under vacuum and stored at -20°C had peroxide value of 7.98 meq O₂/kg fat, free fatty acids (% oleic acid) 3.15, lightness 80.6, total plate count 3.9 × 10² cfu/ml,

yeast and mould 0.8 × 10² cfu/ml, hardness 1.82 N, springiness 0.82 mm after 20 days of storage and were found acceptable with overall sensory score of 8.2. The peanut paneer is comparable with the dairy paneer with respect to nutritional composition as well as sensory properties, and the cost of peanut paneer at the rate of ₹ 75/kg is much lower than the dairy paneer (₹ 180/kg) with the added advantage of phytochemicals, niacin (vitamin B₆), iron and copper. The technology has been transferred to nine entrepreneurs.

Microencapsulator for probiotics and enzymes: Encapsulated probiotics are used for various purposes such as animal disease management to reduce use of antibiotics, poultry feeds for effective feed conversion, etc. A microencapsulator was designed for the production of wet alginate micro-capsules ranging in size from 3 mm to around 500 µm. The capacity of the system is 3 kg wet alginate micro-capsules/batch of 8 hr. The estimated cost of the system is ₹ 300,000 with operating cost of ₹ 1,500 to 2,500/kg of wet capsules, depending on the strain of the probiotic organisms.



Microencapsulator for probiotics and enzymes

Pilot plant for growing and processing of tender wheat shoot into powder: A multi-tier rack growing system for tender wheat shoot cultivation and a pilot plant for production of tender wheat shoot powder were developed to facilitate wheat powder availability round the year. The present pilot plant, having capacity of 1kg powder/day, consists of a grinder and a cyclone separator. The cost of the complete system requiring 1.5 kW electric load is ₹ 3.2 lakh. It is estimated that this plant would result a profit of about ₹ 1,000/day and will be a successful, rural-based, women-managed cottage level unit. The tender wheat shoot powder contains 38.1% proteins, 0.83% fat, 35.6% carbohydrates and 16.3% fibres on dry matter basis and is rich with vitamins A, B₁, B₂, B₃, B₅, B₆, B₇, B₉, C, E and K.

Peeler-corer-slicer for pineapple processing: This hand-operated device consists of a stainless steel central sleeve to which a slicing plate is attached in a spiral form. Once the slicer penetrates into the whole fruit (cut from both ends), it cuts internal core and external peel at a time. The pulp slab is separated and sliced with the device. By using this device, which costs

only ₹ 500, about 20 pineapple fruits can be easily peeled and sliced in one hour by a skilled worker. Traditional processing using a knife could accomplish these operations for 4 to 5 fruits/hr. The annular ring-shaped pineapple slices cut by this device are suitable for canning and osmotic dehydration.

Coriander seed splitter: The coriander seed is split into two halves prior to sowing. The present practice of splitting is manual which involves drudgery in operation, besides losses in terms of seed damage. A power-operated machine of 60 kg/hr capacity was developed for splitting coriander seed. The machine is equipped with two rollers rotating at differential speed to break coriander seed into two halves. The machine is suitable to split coriander seed with the moisture content up to 14% to give 98% splitting efficiency. This machine costs ₹ 12,000, powered by 0.75 kW electric motor.

Winnower-cleaner-grader for millets: This manually-operated machine, weighing 60 kg and costing ₹ 6,000, has a capacity of 250–300 kg/hr for winnowing-cleaning-grading of millets. The machine, with some adjustments can also be used for other grains such as wheat, paddy, lentil, soybean, etc.

Non-marketable potatoes for production of animal feed and dietary fibre: Processing of potatoes into chips, flakes and powder involves various steps. During processing of potatoes, pulp, slicer fines, chips, peel and rejected potatoes are obtained as byproducts. The total quantum of these materials is approximately 15% of the total processed potatoes. These byproducts were successfully used in the production of animal feed pellets. The compound mix of byproducts was added to other ingredients namely barley, maize, oilcake, mineral mixture and husk up to 25–30%. The protein, fat, moisture and ash in feed were observed to be 13.9, 4.5, 12.6 and 6% respectively. The neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin and cellulose content of the feed were 35, 13.4, 2.5 and 13%, respectively. The physico-chemical characteristics of the mix met the requirement of compound cattle feed and was fed to milch cows by



Animal feed pellets using potato by-products

four dairy entrepreneurs and preliminary results indicated 7–10% increase in milk yield.

Handloom for weaving jute-based decorative and ornamental fabric: A handloom was developed with jacquard shedding arrangement to weave jute-based ornamental fabrics as well as traditional cotton *saris* or other fabrics from 100% jute yarn as well as jute-blended yarns. Apart from the jute, 100% cotton, 100% synthetic and jute/cotton union or jute/synthetic union fabrics may also be produced in the same machine. The fabrics produced in this loom were found elegant, ornamental and excellent in texture with natural look. The fabrics showed good tenacity (2.3–2.6 cN/tex), air permeability (50–55 cm³/cm²/sec at 5mm water gauge pressure) and flexural properties (bending modulus 4–5 kg/cm²). The maximum shrinkage in any direction (even in boiling water up to 30 min) was 1.5% which is well within the permissible limit of 5%.



Handloom to weave jute-based ornamental fabrics

Geo-textile application in the field trial for construction of concrete road: A novel jute-manmade fibre-blended composite structured woven geotextile was developed which is suitable for construction of plain cement concrete road. The geotextile (area density ≈ 575 g/m²) contains minimum 65% jute (w/w). The property parameters conform the standard set by ASTM/BIS and cost of geotextiles including placing cost is ₹ 75/m². The geotextiles is suitable for using as separation material replacing conventional brick soling. Replacement of brick soling would save a substantial quantity of construction material and cost for construction of rural concrete road. Field trial conducted at Mayureswar, Birbhum district in West Bengal for construction of a plain cement concrete road showed a saving of ₹ 65/m² of construction area.

Higher economic returns to cotton farmers and allied stakeholders: Under the study 'Value Chain for Cotton Fibre, Seed and Stalks: An Innovation for Higher Economic Returns to Farmers and Allied Stake Holders', cotton was cultivated in the farmers' fields employing standard cultivation practices which resulted in about 15–20% higher yields. The farmers were given training on clean cotton picking to get cleaner cotton with trash content less than 1.5% and minimum



Fabric and shirt made of clean cotton

contaminants. The farmers could fetch premium price for their produce (about ₹ 200/q or more). In addition, the methodology of cotton stalk collection was demonstrated and implemented in farmers' fields. Farmers could get ₹ 500/tonne of clean cotton stalks and after chipping could get ₹ 1,200/tonne. The harvested cotton was ginned in an established modernized ginning factory using state-of-the-art technologies and converted into bales. Individual bales were tagged with quality attributes. The bales were converted into 30s combed yarn in established spinning mill and converted into fabrics. The prepared fabric was processed in a modern processing house to impart wear comforts and then converted into shirts.

Supply chain for cotton stalk: A cost-effective supply chain mechanism was developed for collection, cleaning, chipping and transportation of cotton stalks from fields to factory. This methodology was demonstrated to cotton farmers all across the country and as a result more than 300 farmers in cotton growing areas of Maharashtra were benefited.

Fruits: Storage-life of **mango**, **sapota** and **custard-apple** could be extended without any chilling injury at 8–12°C by modified atmosphere (MA) packing with semi-permeable film. Similarly, storage-life of papaya (cv. Taiwan Red Lady) could be extended up to one month when the fungicide-treated fruits were MA packed, and such papaya fruits ripened to bright yellow surface colour without any shriveling. The storage-life of aonla could be extended to two weeks without quality deterioration at 15°C by using PE lining (100-gauge) around the fruits. It was recommended that final moisture content in osmotically dehydrated aonla segments should be maintained at 12–13% for better quality retention during storage.

Osmotically dehydrated slices of **Alphonso**, **Dasheri**, **Totapuri** and **Arka Anmol** mango prepared using standard process, dried to a moisture level of 12–15% and packed in punnets could be stored up to one year. Processes for preparation of **banana wine** from cv. Robusta with golden colour, pleasant banana aroma, 11% alcohol and less than 0.5% residual sugar and **sapota wine** with 10–11.5% alcohol, 0.44–0.57%

acidity, and 0.26–0.28% residual sugar were standardized. **Fruit punches** prepared by blending pulp/juice of aonla, mango, passion fruit and custard-apple in equal proportion and beverage concentrates with TSS of 58.5 and 61°Brix and acidity of 2.37 and 2.83 were prepared. The fruit punch comprising aonla, mango and passion fruit was judged as the best due to better taste and flavour. A technology was developed for utilization of waste generated by **mango processing industries** at finished pulp stage. A dietary mango fibre (50 mesh size) was extracted from the waste and incorporated in biscuits. These biscuits are low in calories, rich in antioxidants, vitamin C, high in dietary fibre and have shelf-life of more than six months. Oil of high cosmetic value extracted from mango kernel comprised fatty acids, viz. palmitic, stearic, oleic, linoleic and myristic acids. A face scrub was developed using mango peel, kernel and kernel oil as basic ingredients.

The **litchi wine** from litchi fruits having high nutritional value was prepared by fermentation using wine yeast (*Saccharomyces cerevisiae* var. *bayamus*). The level of juice TSS (25°Brix), pH (3.85) and yeast concentration (6 ml) produced good quality wine with 10.7% alcohol, least reducing sugar (8.75%) with acidic in taste (0.59% citric acid).

In **grapes**, bunch treatment with 15 ml ethyl oleate + 30 g potassium carbonate for 2 min lowered moisture content and colour intensity after 10 days of drying under raisin shed. Similarly, covering of bunches at veraison stage resulted in low colour intensity after drying. Dipping bunches in a solution of 15 ml ethyl oleate and 25 g potassium carbonate for 6 min resulted in better quality raisins. The technology for making novel osmo-dehydrated products of temperate apricots was standardized.

Potato and tuber crops: A simple method for estimation of reducing sugar in **potato** in field using Benedict's reagent was developed. Dipping potato slices in magnesium chloride (0.5%) and calcium chloride (0.5%) for 10 min resulted in 3.7% reduction in oil content of chips.

The functional pasta was prepared from the orange-fleshed **sweet potato** variety ST 14 having high carotene content of approximately 14 mg/100 g, along with *maida* and whey protein concentrate. Due to slow digestibility of starch over a period of 2 hr, sweet potato pasta could be considered as an ideal food for diabetic and obese people.

Extrudates were prepared from **cassava** blended with defatted soybean, pearl millet, sorghum, potato and rice flour in varying proportions. Highest expansion ratio was obtained for cassava-rice flour extrudates. Quick cooking dehydrated cassava and *Amorphophallus* tubers were developed to reduce bulk during export and to increase shelf-life of product with a cooking time of only 2–3 min. Edible biofilms were developed from cassava starch using hydrocolloids like gum acacia, gum tragacanth and xanthan gum, and hydrocolloids improved film-forming property of starch.

Particle boards with a density of 740–880 kg/m³ were developed from waste cassava stems blended with resin and wax.

Floriculture: In orchids, post-harvest treatments with 4% sucrose + 1% Ca(NO₃)₂, 4% sucrose + 100 ppm salicylic acid and 4% sucrose + Al₂(SO₄)₃ (100 ppm) improved opening of maximum number of buds, least bud drop and highest vase-life (27 days) in *Cymbidium* hybrid 'Ensikhan'. On impregnation of cut spikes of *Cymbidium* 'Baltic Glaciers', highest longevity was recorded with CaCl₂ (1,000 ppm) for 15 min (46 days), followed by CaCl₂ (1,500 ppm) for 15 min (44 days) over the control (39 days). The pulsing of flowers for 2 hr with 5% sucrose, followed by 150 ppm 8HQS increased vase-life of *Cymbidium* cut flowers with pollinia was 49.33 and 46.33 days and without pollinia 44 and 41.67 days.

Spikes of *gladiolus* harvested at 5–6 florets showing colour was the most suitable stage for wet refrigerated storage (up to 12 days). Pre-storage pulsing with hydroxy quinoline (HQ) @ 500 ppm with 5% sucrose was standardized for cut orchid spikes (Kahikuchi). Wet storage up to six days in Al₂(SO₄)₃ at 300 ppm at 2°C was found optimum for improving vase-life in rose cv. Grand Gala (Ludhiana). Holding solution consisting sucrose (5%), Al₂(SO₄)₃, 16H₂O (300 ppm) and kinetin (25 ppm) showed best result of post-harvest quality and life of anthuriums (Coimbatore). Vase solutions with sucrose (5%), Al₂(SO₄)₃, 16H₂O (300 ppm) and sucrose (5%) with BAP (25 ppm) significantly improved vase-life of cut spikes of *tuberose* (Kalyani). The spikes wrapped with polypropylene sleeves along with KMnO₄ before transit improved the flower longevity of cut spikes of *Dendrobium* Cv. Pompadour (Kahikuchi).

Mushroom: In button mushroom, combined washing treatment of 100 ppm EDTA with 0.02% KMS gave whitest mushrooms. Mushrooms packed in 100-gauge polypropylene bags gave better results with respect to retention of whiteness, lesser loss in weight and veil opening on their storage both at refrigerated and ambient temperature conditions. Blanching, followed by sun-drying gave better results with respect to whiteness, brittleness and keeping quality even after three months of storage in oyster mushroom. Drying experiment on milky mushroom showed best results with blanching, followed by sun-drying, while cabinet dried (40±2°C till 7% moisture) milky mushroom gave better results with respect to retention of whiteness, brittleness and keeping quality after three months of storage.

Feta cheese from buffalo milk: Feta cheese, soft white-brined cheese is traditionally made from sheep milk or from mixture of sheep and goat milk. To meet its ever increasing demand throughout the world, cow milk was used successfully for its production but it has to be bleached to get the desired white colour. However, bleaching destroys the valuable nutrients β-carotene. As such, buffalo milk contributes more than 57% to the total milk production in India, which



Feta cheese

could be a potent candidate for the manufacture of such cheeses. There is also a great scope for export of feta cheese as its mild acidic flavour is liked by consumers. A good quality feta cheese was developed with enhanced functional attributes from buffalo milk. To obtain an acceptable quality feta cheese, processing parameters such as C/F ratios, heat-treatments, type and level of starter culture, level of rennet, brine condition, level of rennet and brine concentration were studied and an appropriate feta cheese manufacturing technology was developed.

Nanoparticles of gold and silver prepared and partially characterized: Nanoparticles possess unique property of flow and on it ligands can be attached. This makes them very useful in lateral flow system in diagnostics. Nanoparticles of gold were prepared in the laboratory from reduction of gold chloride by citrate. New reducing agent, amino naphthol sulphonic acid was attempted and this reducing agent could also be used for preparation of gold nanoparticles. Gold nanoparticles showed characteristic lambda maximum at about 529 nm. Silver nanoparticles were also prepared from silver nitrate using sodium borohydride as reducing agent. Preliminary results showed that stability of silver nanoparticles was poor in toluene when transferred from aqueous phase to toluene.

Three-stage thin film SSHE for continuous manufacture of rabri: Three-stage SSHE was made for continuous manufacture of *rabri*. The process and machine parameters were optimized in terms of sensory attributes and product quality. Trials were conducted by changing mass flow rate, type of sugar, acidity of milk and rotor speed of first and second stage SSHE. Data indicated that acidity had significant effect on body and texture and caramelized sugar had significant effect on flavour and colour. The fine flakes of homogenous mass were well formed by keeping third stage SSHE at low rotor speed with required acidity level. The feasibility study clearly established that *rabri* can be manufactured continuously in three-stage SSHE having capacity of 40 kg/hr of product formed.

Camel milk whey proteins: In camel milk, the whey proteins showed a pronounced heat effect only at 90°C, where bands intensity decreased without totally disappearing. No visible heat effect on camel milk

SUCCESS STORY

Sweetened whey lemon beverage: Whey lemon beverage is a highly nutritious dairy product containing lactose, protein, minerals and water-soluble vitamins. Technology was developed for preparation of shelf-stable low calorie artificially sweetened whey lemon beverage using a binary sweetener blend.

Benefits of the technology

- Maximum synergy with the best binary blend in sweetness intensity and overall acceptability (17.5%, 9.0%) with respect to single sweetener aspartame.
- Multiple sweetener approach involving use of binary blend resulted in 29% reduction of usage level when compared with single sweetener aspartame.
- Artificially sweetened whey lemon beverage using binary sweetener blend resembled sucrose sweetened whey lemon beverage in all the sensory attributes up to 5 days of storage (6-8°C)
- Binary sweetener blend retained its stability in whey lemon beverage throughout the storage period of 15 days as revealed by HPLC analysis.
- 61% reduction in calorific value in comparison to sucrose sweetened whey lemon beverage.
- Cheaper than sucrose sweetened whey lemon beverage.

whey proteins was observed at 80°C pasteurization.

Camel milk powder: Camel milk powder was prepared by lyophilizing raw, pasteurized and boiled camel milk. Highest yield was observed for the powder prepared with boiled camel milk, followed by pasteurized camel milk. Overall acceptability was same for both types of lyophilized powder.



Gulab jamun prepared by using camel milk powder

Designer paneer from yak milk: A study was undertaken to develop dietary fibre enhanced low fat yak milk paneer. Decreasing the milk fat to 1% significantly increased the density of the yak milk. Among the different dietary fibres evaluated, inulin proved to be the best with regard to its ability to improve quality attributes of low fat yak milk paneer. Dietary fibres-enhanced low fat paneer was evaluated for various physicochemical, proximate, microbiological and sensory attributes. Full fat yak milk paneer can be stored up to 9 days at refrigerated storage, whereas designer paneer (inulin incorporated low fat paneer) can be stored up to 12 days at refrigerated storage.

Mithun milk proteins: its characterization and bioactive properties: SDS-PAGE pattern of whey protein of mithun colostrum was compared with mithun cross and crossbred cattle milk whey protein.

Differences in band pattern between mithun colostrum whey and others were observed with respect to band intensity. The bands corresponding to 104 kDa (immunoglobulin), 65.5 kDa (bovine serum albumin) and 28 kDa (an unidentified band) were found much thicker in mithun colostrum whey sample compared to others.

Meat and meat products technology

Crispy goat meat products: Formulation for crispy goat meat products with cereal base filler was standardized and technology is ready for commercialization and cost of meat product can be substantially

Meat products

- Incorporation of combinations of carrot, radish and cauliflower in chicken nuggets significantly improved physico-chemical and sensory characteristics.
- Use of 10% level of sunflower oil produced low-fat goat meat balls of similar sensory characteristics as that from 15% animal fat.
- Sensory evaluation of the meat for juiciness, tenderness and its overall palatability was better in kids given 40 ppm organic zinc in comparison to 40 ppm inorganic zinc.

reduced. These meat-based snack products can be safely stored for six months at room temperature in the nitrogen-filled packs.

Retort pouch processed meat products: Meat products such as mutton and chicken curries, nuggets, sausages were retort pouch processed as shelf-stable ready-to-eat meat products, which require no refrigeration for their transport, distribution and marketing and could be beneficial for development of the processed meat sector in India.

Goat meat nimkee: The technology for preparation of goat meat *nimkee*, a shelf-stable meat snack was developed to address the nutritional concerns of the snack foods. The product is rich in animal protein (14%), high dietary fibre (8%) and fortified with natural

Goat meat murukku

Meat snacks were innovated to prevent rapid spoilage and help easy transportation. A simple consumer-friendly and commercially viable goat meat *murukku*, a shelf-stable meat snack was developed. It has come as a respite for the meat processors across the country. This product is packed in a modified atmospheric packaging technique and is a functional food. It is rich in animal protein (16%) and fortified with dietary fibre (10%) and herbal extracts having natural antioxidant effects. The product is free from trans fat and less in cholesterol. It can be stored at room temperature for six months without any appreciable changes in its quality. The production cost of 100 g of goat meat *murukku* is only ₹ 15 under small-scale level of production.

The product has been commercialized and efforts are being made for patenting this consumer-friendly meat snack.

SUCCESS STORY

Functional chicken nuggets with low salt, low fat and high dietary fibre

Functional chicken nuggets with low salt, low fat and high dietary fibre were developed without any adverse effect on sensory and technological qualities. Five different sources of dietary fibre—two grain hulls, two vegetables and one fruit pulp—were used to enhance the fibre content of the nuggets.

The functional nuggets have very good yield and high protein, high dietary fibre and less fat content than control along with significant reduction in total lipid, cholesterol and sodium contents. In sensory evaluation, the product was rated as good to very good by the meat consumers. The product is shelf-stable in vacuum packed pouches under refrigerated storage ($4\pm 1^\circ\text{C}$) for more than 12 weeks without any marked effect on sensory, physico-chemical or microbiological quality.

herbal-based bioactive compounds. It is a classic functional goat meat snack product with no trans fat, no added MSG and less cholesterol. The cost of production of 100 g of goat meat *nimkee* was only ₹ 10. The technology is very simple, suitable for small-scale industries and commercially viable. This product can be safely stored at room temperature for six months in nitrogen flushed packing. The institute has filed provisional patent for this consumer- and industry-friendly technology.

Spleen supplemented goat meat nuggets: Nuggets were supplemented with spleen of 14-month-old Barbari goat. Fresh goat spleen was a valuable source of protein and mineral and its supplementation reduced formulation cost and improved nutritive value of meat products. Quantity of spent goat meat can be significantly improved by adding 40-50% meat from young goats. Such goat meat products are highly acceptable to the consumer, as confirmed by sensory evaluation test.

Value-added egg products: Process optimized for preparing premium egg products, viz. egg soufflé, consisted of 55% whole egg liquid, 18.5% cheese strips, 12% skimmed milk powder, 10% sugar along with small quantity of roasted blackgram powder and bread crumbs. The product has a shelf-life of 18 days at 5°C under aerobic packaging.

Value-added poultry meat products from heavy weight broilers: A number of value-added products such as nuggets, croquettes, *idli*, *vada*, slices etc. from chicken meat of heavy weight broilers and cured and smoked products (smoked chicken breast, smoked chicken legs and mutton ham) were produced providing diversified value-added products for the benefit of producers, processors and consumers.

Hide

The leather quality of both mithun and cattle were assessed for physical, chemical and microscopic

Value-added products from fish

- A stuffed fish-based product 'Momo' was prepared using *rohu* along with other ingredients. The quality evaluation showed that fried product was acceptable up to 12 days compared to 16 days for steamed product.
- Fried, RTE fish wafer were prepared from *rohu* filleting waste. The product had a shelf-life of one month in air and 23 days in nitrogen pack.

properties. The hides of both the species (grain surface) were scanned by using electron microscope after tanning by chrome tanning methodology. It was found that

- Hide processed with intact hair had good usability as exotic outer cover for sofa.
- Bag leather produced with mithun hide is soft and having much better body and roundness as compared with conventional leathers produced from cow hides. Shoe upper leather is also better with wares made from conventional cow hides.

Identification of food-borne pathogens in seafood:

Antibacterial fractions obtained from extracts of different plant sources like grape seed, bilimbi fruit, noni fruit, pomegranate epicarp and malabar tamarind were shown to possess broad spectrum activity against some of the major food-borne pathogens encountered in seafood. A microtitre-based assay protocol using resazurin indicator was developed for determining minimum inhibitory concentration of antimicrobial extracted from plant-based sources.

Cadalmin™ GMe extracted from green mussel: Cadalmin™ GMe, an extract from green mussel *Perna viridis*, is found effective to combat chronic joint pain, arthritis/inflammatory diseases and improves cardiovascular functioning. It contains 100% natural marine bioactive anti-inflammatory ingredients and is a blend of nutraceutical and nutritional elements. This product is designed to find a unique way to prevent the degradation by air, moisture, heat and light and to maximize the activity. The product is free from deleterious trans fatty acids, free radicals/free radical adducts, and low molecular weight carbonyl compounds.

Gelatin from fish processing waste: Gelatin was developed utilizing waste from fish, Ghol (*Protonibea diacanthus*), a marine fish, having the potential of abundant supply of raw skins. Response surface methodology was adopted by following central composite design to determine the optimal conditions of four independent variables (concentration of NaOH, soaking time, extraction temperature and extraction time) for three response variables namely yield, gel strength and melting point. The maximum gelatin yield was 19.19%, gel strength 439 g and melting point 23.7°C . Ghol skin, available in sufficient quantity in fish processing industry is a prospective source to produce gelatin in good yield with desirable quality attributes comparable to commercially available mammalian gelatins.

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