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Technological Innovations in Food Processing and Value Addition to Coconut

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Abstract: Consumers demand for high quality foods that are fresh tasting and nutritious have created considerable interest in the development of new food-processing techniques. Developments in non-thermal technologies have been advanced by both industry and academia in an attempt to meet the challenge of producing safe processed food of a high quality. These techniques may be adopted for liquid products like coconut sap, tender coconut water and mature coconut water to achieve sterility with extended shelf life. A diverse range of other food products has also been prepared from coconut that satisfies the human nutritional and health requirements. Value added products developed from coconut includes Beverage, Yoghurt, Jam, Jelly, Chips, Spread, Milk, Spray dried coconut milk powder, Coconut cream, Copra, Neera, Coconut chutney, Dehydrated coconut chutney, Nata-de-coco, Vinegar, Virgin Coconut Oil (VCO) and VCO meal based products, etc.

Keywords: Coconut, Value addition, Preservation, Processing, Shelf life.

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1. Introduction

In a world where we produce enough food to feed everyone, the United Nations Food and Agriculture Organization estimate that about one in nine (almost 821 million), go to bed hungry each night (www.downtoearth.org.in/Food insecurity report). Even more – one in three – suffer from some form of malnutrition. Hunger causes more deaths than Malaria, HIV and TB put together.

The concept of the Sustainable Development Goals (SDGs) was born at the United Nations Conference on Sustainable Development, Rio+20, in 2012. 2030 Agenda for Sustainable Development was adopted (Resolution 70/1) on 25 September 2015 at the United Nations in New York. It comprises 17 new SDGs,

beginning with a historic pledge to end poverty. The aim of UN Sustainable Development Goal 2 is to 'End hunger, achieve food security and improved nutrition, and promote sustainable agriculture' (in.one.un.org/sustainable-development-goals). One of the main objectives is to ensure sustainable food production systems and implementation of resilient agricultural practices which increases productivity and production, that help to maintain ecosystems and to strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

This is being achieved by investments in Food Security and Rural Development to ensure sufficient, safe and nutritious food. Rural Development encompasses creating business opportunities and job in Crop based sectors, Food processing and Horticulture enterprises.

1.1. Indian Food Scenario

To start within 1947, India was not self-sufficient in food grain production (ship to mouth era). India recorded impressive achievements in agriculture in a span of three decades since the onset of green revolution that transformed India from a food deficient stage to a surplus food market.

India is endowed with substantial agriculture resources with over 180 agro-climatic regions, forests and a vast coastline. 141 million hectares (52%, against 11% global average) of total cultivable land is a giant resource besides huge irrigated lands and enough supply of Skilled, educated, technical and scientific workforce. Our farmers are the backbone of country's food security. Agriculture is the primary source of livelihood for about 58 per cent of India's population. Gross Value Added by agriculture, forestry and fishing is Rs 18.53 trillion (US$ 271.00 billion) in 2018. Food and grocery account for around 31% of India's consumption basket (Madhusudhan, 2015). In terms of agricultural produce, poultry and meat output, India is ranked second in the world as shown in (Table 1).

Table 1: Production status of food commodities (2018-19)

Commodity	*Production*	*Status in the World*
Milk	187.7 Million tons	Largest Producer
Livestock	535.78 Millions	Largest Producer
Grains (Rice, Wheat)	275 Million tons	Largest producer
Vegetables	178.2 MMT	2nd largest producer
Fish	13.7 MMT	2nd largest producer
Fruits	97.97 Million tons	2nd largest producer
Eggs	100 billions	3rd largest producer
Oilseeds	34.19 Million tons	4th largest producer

India ranks fifth in terms of production, consumption and exports. The Indian food and grocery market is the world's sixth largest, with retail contributing 70% of the sales. Growth rate in agriculture and allied sector has been approximately 4.4%. India has a diverse regional and cultural demographic structure. The main challenge before the Indian Agro-Food industry is to guarantee the availability of safe and healthy food against the background of increasing consumer demands, sustainability concerns as well as resource demands for bio based applications. Added to this, climate change, the intensified competition for energy, more and more requirements for fresh water, agricultural produces and agricultural land as well as the shift in dietary patterns has created more challenging tasks to this sector. Government of India is focusing on improving production and productivity of crops mainly under the National Food Security Mission and National Horticulture Mission.

2. Food Processing

Consumers demand for high quality foods that are tasty, wholesome, nutritious and processed in such a way so that the functionality and bioavailability of their bioactive components is retained to the maximum, have created considerable interest in the development of new food-processing techniques. Consumers are also increasingly becoming aware of nutritional security and about the food safety. Food processing is mainly to preserve food and to ensure safety (kill microorganisms), increase digestibility, increase shelf life (destruction of enzymes, toxins), help in improving palatability and organoleptic quality (texture, flavour, colour), increase seasonal availability of many foods and develop new products (www.newworldencyclopedia.org). Food processing makes available for a consumer a wide variety of foods and, as a consequence, they have a more convenient, safe and affordable diet.

2.1. Genesis of Food Processing

Modern food processing technology developed in the 19th and 20th centuries in a large part to serve military needs. During the Napoleonic era, with the French military spreading its influence geographically, the challenge of feeding the army and navy became an acute problem. Napoleon Bonaparte offered a monetary reward (Napoleon's Food Preservation Prize, 12,000 francs, 1795) for a practical solution for preserving food. The French confectioner Nicolas François Appert rose to the challenge, experimenting over the next 14 years in search of a satisfactory food-preservation method. He devised a method involving heating, boiling and sealing food in airtight glass jars — the same

basic technology still used to can foods and published a Book entitled L'Art de conserver les substances animals etvégétales (The Art of Preserving Animal and Vegetable Substances). Pasteurization, discovered by Louis Pasteur in 1864, improved the quality and safety of preserved foods and introduced the wine, beer and milk preservation. India has a rich heritage of traditional and ethnic foods that need to be preserved. This treasure has to be unraveled, adopted in its originality or combined with new global food technology concepts to innovate great foods, which can put India on top of the world food map.

2.2. Post-harvest Management

Though India has a large production base, our productivity is low. Harvest and post-harvest loss of India's major agricultural produce is estimated at Rs 92,651 Cr ($13 billion), according to data published by the Ministry of Food Processing Industries on August 9, 2016 (www.ciphet.in). We waste as much food as the whole of UK consumes. Post-harvest losses could be minimized by Good Agriculture Practices, Good Animal Husbandry practices, Good Manufacturing Practices, Good Hygiene Practices and Food Processing. The Indian food industry is poised for huge growth, increasing its contribution to world food trade every year due to its immense potential for value addition, particularly within the food processing industry. The post-harvest management (PHM) system implies the delivery of a crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and maximum return for all involved. In order to reduce the postharvest losses, there is a need to adopt proper strategies involving new technologies in the PHM.

2.3. Value Addition to Food Products

Better and improved PHM practices, diversification, value addition and exports are the key needs for Indian horticulture sector in the coming years. Value addition to foods may be done by several ways. It could be done by the use of preservative, food ingredients capable of eliciting functionalities and by fortification using micronutrients. There are novel and emerging food processing technologies that are possible to preserve the ingredients in the food intact (Sharma, 2017; Sharma, 2018). The shelf life enhancement of the processed food can be done by adapting newer packaging technologies. The by-products of the fruits and vegetables, etc., may be used for value addition by adapting commercially viable approaches. Fermented foods are value added foods that could be developed using novel starters. Starter cultures

are those microorganisms (bacteria, yeasts, and molds or their combinations) that initiate and carry out the desired fermentation essential in manufacturing cheese and fermented dairy products. India is fast emerging as a sourcing hub of processed foods.

2.4. Technological Innovations in Food Processing

Various technological innovations in the food processing sector is a must for meeting the growing food demand, alleviating food security gap and to account for more and more urbanization that reduces agricultural production but enhances the food consumption.

2.4.1. Thermal Processing Technologies

It comprise of sun drying, cabinet drying with additive treatments, high temperature short time (HTST), pneumatic drying, cold shock dehydration, fluidized bed drying, spray drying, retort processing, pasteurization, microwave processing, infra-red processing and extrusion technology (Sharma and Wadikar , 2016; Anilakumar *et al.* 2017). Many types of food products available in the market that uses thermal technologies for processing include Ready-to-Eat (RTE) Meals, RTE bars and biscuits, RTE jam, preserves and jellies, RTE pickles, dehydrated food products, semi-processed convenience food products (precooked and dehydrated/ instant/jiffy) and canned food products. Most of the thermally treated food products are preserved by subjecting to high temperatures for a few seconds or several minutes which may lead to loss of vitamins, essential nutrients, colour and flavor. To overcome or minimize these disadvantages, the concept of non-thermal process was explored. Usually, these processes are operated at room temperature so that vitamins, essential nutrients, colour and flavor will be protected with minimal or no loss. In addition to this, non-thermal process can also be effectively used for enzyme and microbial inactivation.

2.4.2. Non-thermal Processing Technologies

It is an emerging trend in food processing in view of better retention of nutritional quality of the product. The main challenge in non-thermal processes is standardization when compared to thermal treatments. Non-thermal processes seem to be product specific hence it need additional research work to define process parameters. The advantages include better nutritional values, better sensory and microbiological quality and minimal or no use of preservatives. Non-thermal processing technologies includes Ozonation,

Ultrasonic processing, High hydrostatic process (HHP) processing, Pulsed UV light, Pulsed electric field (PEF) for liquid food and beverages, Cold plasma processing, Gamma irradiation, Freeze drying, Minimal processing, Hurdle technology, Reverse osmosis and Ultrafiltration, Use of antimicrobials and bacteriocins, etc. Developments in non-thermal technologies have been advanced by DFRL in an attempt to meet the challenge of producing safe processed food of a high quality. These techniques have been adopted for liquid products like coconut sap, tender coconut water and mature coconut water to achieve sterility with extended shelf life. Each of these technologies has specific critical process parameters that must be monitored as part of critical control points. In-depth understanding of these technologies is the key while considering their implementation.

Development of newer processing technique that are energy efficient, new food product development, innovation and fusion is the way ahead to succeed under competitive global economy (Sharma *et al* 2016).

3. Drivers for Sustainable growth of Value added Food Products for Defence Forces with Spin Offs to Civil Sector

Defence Food and Research Laboratory (DFRL), Mysore, a constituent laboratory of Defence Research and Development Organisation (DRDO), is into military nutrition and feeding of over 12.5 lakhs combatants. DFRL develops technologies to find new sources of food products, add convenience, increase efficiency, reduce costs and increase export. DFRL has been focused with its efforts to conserve, preserve, stabilize, design, fabricate and engineer a vast array of specific food products of Indian dietary, which are not only shelf stable under all weather conditions but also deliver adequate nutrition and energy to keep the morale of Service personnel high at all times (Sharma, 2017; Sharma and Wadikar , 2016; Anilakumar *et al.* 2017; Khanum et al 2017).

3.1. Need for Processed Food for Indian Military and Paramilitary Services

In operational situations, the soldiers are at times deprived of the fresh produce needed to sustain life processes. At some locations even normal regime of cooking becomes extremely cumbersome and difficult. We aim at inspiring trust by creating a culture of food safety and nutrition security amongst defence forces and assuring them availability of a variety of long-lasting, convenient, wholesome, healthier, nutritious, delicious, tastier, appealing and quality food around the year in abundance-even for those deployed at inhospitable locations

and landlocked areas and for critical missions like Antarctica and manned space flight. Making Terrain, Theatre, Operation and platform specific food products is our main forte to keep our soldiers, airmen and sailors healthy, fit and happy (Sharma, 2017). The R&D efforts at DFRL are aimed at developing lightweight, convenience pack rations for army, navy, air force and other paramilitary forces, which do not require any elaborate cooking or preparation at the consumer's end and remain shelf stable under varying climatic conditions for periods ranging from 6 to 12 months. Through enormous and substantive contributions, DFRL has developed a wide variety of food products of Indian dietary matching the mainframe palate tastes of the country.

3.2. Spin Offs of Processed Food to Civil Sectors

Food processing sector is rapidly evolving as an important segment in strengthening India's role on the global platform of processed food. Frozen, Meals-Ready-to-eat (MRE/RTE), Ready-to-cook (RTC) or Ready-to-drink (RTD) packaged food is also gaining popularity in civil sector with growing demand for processing food. Indigenous ingenuity is the hallmark of most of the technologies, processes and products developed at DFRL. Many of the DFRL foods, born out of innovative state-of-the-art technologies, lend themselves eminently suitable to industrial scale commercial exploitation by enterprising entrepreneurs of different genre (Murugan *et al.* 2015; *www.drdo.gov.in*, 2017). There is a high market potential of such processed foods in India mainly due to following factors:

- Increased literacy, urbanization and rising disposable income
- Increasing number of dual income nuclear families and increase in the number of working women
- Busy and changing lifestyle,food habits, tastes and shift in consumption habits
- Growing trend of less time spent in kitchen
- Increasing pattern of spending on healthy and value added food with higher shelf life, greater nutritive value and that takes less time to cook
- Large and growing domestic consumer market
- Products diversification (Products lifecycle - fairly vast array of products of Indian dietary, which are not only shelf stable under all weather conditions but also deliver adequate nutrition and energy with fascinating USP) and Mass production practices
- Convenience of consumption (during travel in India and Abroad)

Some of the simple technologies could be taken up by small and medium scale industries to bring traditional foods and/or fast food products to consumers at comparatively competitive and affordable rates. DFRL has more than 500 technology transfers to its credit, thus, contributing to employment generation, vendor generation for armed forces and 'Make in India' initiative of the Government of India in food sector. DFRL has also produced many food products which are exports worthy.

4. Advanced Technologies Pursued at DFRL for Processing and Preservation of Food Products

DFRL has been developing/adopting important food processing technologies for value addition to the food products such as retort pouch processing and high pressure processing for salads and ready meals, Pulsed electric field processing for liquid foods and beverages, high intensity electric field pulses on solid foods and enzymatic inactivation by pulsed electric fields, etc. (Murugan *et al.* 2015; Sharma, 2016; Anila *et al.* 2017; Khanum *et al.* 2017; *www.drdo.gov.in*, 2017). Some advanced technologies pursued at DFRL for processing and preservation of food products are as follows:

4.1. Retort Pouch Processing

It is a unique combination of packaging, processing and product development technologies with functional, quality and economic benefits. Retort pouch processing is used to keep food products into shelf stable at room temperature without the necessity of freezing, cooling and drying. This processing aims to preserve foods for a long period of time at ambient conditions with ensured safety and minimum quality loss. It is to prevent processed food products from being spoiled even at room temperature by inactivation of spoilage microorganism through retort pouch processing after packing in air-tight container (pouch). The product is sealed into an air tight container (hermetically sealed). Heat treatment is applied in order to destroy pathogenic microorganism and mesophilic microorganisms its spore / toxin and inactivate the thermophilic organisms. Heat treatment process must be designed and controlled in such a manner to provide the required safety, at the same time leave the product values and quality factors.

4.2. Ohmic Heating Technique

It is used as a thermal method to preheat, to blanch and to pasteurize and sterilize vegetable products, fruit preparations and meat products. The process

is based on using the electrical resistance of the food being treated. Dissipation of the electrical energy when an electric current flows through food causes heat to be released (Joule effect). The amount of dissipated heat is directly related to the applied voltage and the electrical conductivity of the product or of individual product fractions (Ohm's law). The advantages of ohmic heating lie in the heating of the product volume, which, ideally, should be uniform. Depending on the conductivity of individual product fractions, the configuration of the treatment chamber and the flow characteristics of the food, it could be heated at relatively low temperature gradients.

4.3. Pulsed Electric Field (PEF) Technology

It is a non-thermal method of food preservation that uses short pulses of electricity for microbial inactivation while better maintaining the original colour, flavour, texture and nutritional value of the unprocessed food. PEF technology involves the application of pulses of high voltage to liquid or semi-solid foods placed between two electrodes. High intensity Pulsed Electric Field (HIPEF) processing involves the application of pulses of high voltage (typically 20-80 kV/cm) to foods placed between two electrodes. PEF treatment is conducted at ambient, sub-ambient or slightly above ambient temperature for less than 1 s, achieved by multiple short duration pulses typically less than 5 μs and energy loss due to heating of foods as well as undesirable changes in the sensory properties of the food is minimized. PEF treatments are very effective on the microbial inactivation in milk, milk products, egg products, juice and other liquid foods.

4.4. Ultra-High Pressure (UHP) Technology

It is a promising "non-thermal" technique for food preservation that efficiently inactivates the vegetative microorganisms, most commonly related to food borne diseases. High pressure processing is carried out with intense pressure in the range of 500-1000 MPa, with or without heat, allowing most foods to be preserved with minimal effect on taste, texture or nutritional characteristics. High pressure technology acts instantaneously and uniformly throughout a mass of food independent of size, shape and food composition. Compression will uniformly increase the temperature of foods approximately 30ºC per 100 MPa. The temperature of homogenous food will increase uniformly due to compression. An increase in food temperature from 900-1100 ºC in conjunction with pressure 500-700 MPa have been used to inactivate spore forming bacteria such as *Clostridium botulinum*. The inactivation effect of high pressure

processing results in extending shelf life and improving the microbial safety of food products. The main advantage of high pressure processing compared to thermal sterilization and pasteurization is maintenance of sensory and nutritional characteristic of treated food products.

5. Coconut - a Versatile Crop

The Coconut tree, a member of the palm tree family and the only known living species of the genus Cocos, is one of the most fascinating and beautiful palms in the world. 'Coconuts' are the fruit of the coconut palm, botanically known as *Cocos nucifera*, (nucifera meaning "nut-bearing"). Coconut is native to Malaysia and Southern Asia, and is now also prolific in South America, India, the Pacific Islands, Hawaii and Florida. Coconut is grown in more than 86 countries worldwide. Southern India alone contributes 90% of area and 91% of production. Indonesia is the world's leading coconut producer which produced about 19 MMT of coconuts and India is the third largest coconut producer with an annual production of more than 21,500 million tonnes nuts. For the first time, India has been exporting dry coconut in large quantities to the U.S and European countries. In 2017-18, India exported coconut worth Rs 1602.38 crore while imports stood at Rs 259.70 crore. Coconut occupies area of more than 21 Lakh Hectares. Coconut is produced in more than 18 states and 3 union territories in India. Tamil Nadu, Kerala, Karnataka and Andhra Pradesh are the leading coconut producing states in India and these states contributes for more than 90% of the total coconut produced in the country.

The coconut palm, supposed to be one of the five legendry 'Deva Vrikshas', has been praised as 'Kalpa Vriksha' - the all giving tree - in the classics of India. Coconut is called a multipurpose crop of the future, widely acclaimed as Tree of Heaven. Coconuts are known for their versatility of uses as there are a series of end products with multifarious uses. Coconut is an inevitable item for cultural and social functions. The term 'coconut' refers to the whole coconut palm, the seed, or the fruit, which botanically is a drupe, not a true nut. The inner flesh of the mature seed, as well as the coconut milk extracted from it, forms a regular part of the diets of many people in the tropics and subtropics. Coconut leaves are used as thatches for roof and fencing. Coconut shell is used as an industrial product and for making handicraft items. Coconut trunk is used as building materials, flooring materials and handicrafts. Coconut is used as food crop, oilseed, fibre crop and beverage crop. Being a natural and eco-friendly product, coconut has a future and potential for earning carbon credits.

5.1. Tender Coconut Water and Neera

Coconut's endosperm contains a large quantity of clear liquid, called 'coconut water' or 'coconut juice'. The water of tender coconut (TCW) is a sterile, nutritious and a thirst quenching natural health drink with gentle taste and flavor (Jean *et al* 2009; Dornier *et al* 2012; Priya and Ramaswamy,2014; Anilakumar *et al.* 2017; Zulaikhah, 2021). It is rich in potassium and other minerals. Sugars form an important constituent of the TCW. The concentration of sugars in the nut water steadily increases from about 1.5 to 5-5.5 per cent in the early months of maturation and then slowly falls reaching about 2 per cent at the stage of the full maturity of the nut. After harvesting, the quality of tender coconut water in nuts is found to undergo deterioration after 72 h.

The TCW has a calorific value of 17.4 per 100g. TCW possess good rehydration properties for patients suffering from gastroenteritis and intestinal disturbances (Zulaikhah *et al.* 2021). It is known to have been administered intravenously during famine and wars (Falck *et al.* 2000). TCW is zero fat, zero cholesterol and zero added sugar drink that is rich in the essential electrolytes like sodium, potassium, magnesium, calcium and phosphorus. Possess therapeutic properties with vitamins, minerals and protein. The coconut palm tree is a valuable medicinal crop around the world. Rich in fiber, vitamins and minerals they provide different health benefits. Coconuts are commonly used in herbal and western medicine as remedy for heart diseases, high blood pressure, digestive and bladder problems, diabetes, bronchitis, cancer, asthma, constipation, diarrhea, stress relief, skin infections, flu, cough, fever, pain, weight loss, cholesterol level, dental care and many others. Coconuts have antiseptic, antibacterial, anti-inflammatory, anti-irritant, antioxidant and soothing emollient effects.

Coconut yields coconut neera and coconut toddy (inflorescence). Tender coconut water is much valued for its delicate taste, aroma and flavour apart from the minerals and other nutrients that it delivers. The endosperm is initially in its nuclear phase suspended within the coconut water. As development continues, cellular layers of endosperm deposit along the walls of the coconut, becoming the edible coconut "flesh".

5.2. Value added Coconut based Food Products Developed at DFRL

A diverse range of food products has been prepared from coconut that satisfy the human nutritional and health requirements (www.thehindubusinessline.com; www.techno-preneur.net; www.oocities.org; Rethinam and Kumar, 2007; Markose and Poduval, 2009; Jean *et al* 2009; Dornier *et al* 2012; Priya and

Ramaswamy,2014; Tamilselvan et al 2017). Value added products developed from coconut includes Beverage, Yoghurt, Jam, Jelly, Chips (Pandey et al 2017), Spread, Milk, Spray dried coconut milk powder, Coconut cream, Copra, Neera, Coconut chutney, Dehydrated coconut chutney, Nata-de-coco, Vinegar, VCO and VCO meal based products (Markose and Poduval, 2009), etc. and described (Table 2).

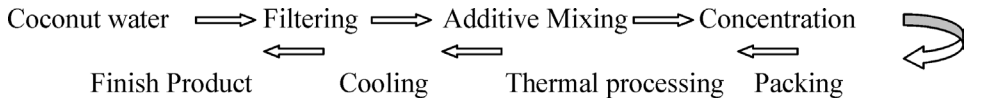
Table 2: Physico-chemical properties of value added products of coconut

Parameters	*Fruit juice blended tender/ mature coconut water beverage*	*Tender coconut jam*	*Coconut chips*	*Virgin coconut meal based bar*	*Virgin coconut meal based biscuit*
pH	3.0	3.3	--	--	--
TSS (°Brix)	15	68.8	--	--	--
Moisture (%)	85	20.2	12.8	15.3	3.5
Protein (%)	0.2	0.4	8.5	11.5	6.3
Fat (%)	0.1	9.8	58.4	14.8	32.2
Carbohydrate (%)	14.8	68.7	14.6	56.5	57.1
Ash (%)	0.1	0.9	2.1	1.9	0.9
TPC (cfu/ml or g)	Nil	$<10^1$	$<10^2$	$<10^1$	$<10^1$
Coliforms (cfu/ml or g)	Nil	Nil	Nil	Nil	Nil
Yeast and molds (cfu/ml or g)	Nil	Nil	$<10^1$	$<10^1$	Nil
Overall sensory acceptability* (*On 9 point hedonic scale)	8.5	8.0	8.2	8.1	8.4

5.2.1. Tender Coconut Water Preservation

DFRL, Mysore, has developed innovative state-of-the-art technology to preserve and stabilize tender coconut water in flexible polymeric pouches and aluminum cans. In fact, the pure and sweet tender coconut is known for therapeutic properties and is a nutritious and a thirst-quenching refreshing health drink for all age groups. The technology enables retention of all the natural goodness and delicate flavour of tender coconut water. The product has a shelf life of six months under ambient conditions. The shelf life can be further extended by three more months under refrigerated storage. Coconut water of 6-7 month stage is first filtered through pressure filters and then mixed with the desired proportion of additives plus sugar and concentrated to the appropriate level. The water is then packed in pouches / cans and retorted in an autoclave, after which it is cooled in a stream of cold water. It helps to retain the flavour of the tender coconut water.

5.2.1.1. The Process Flow of Tender Coconut Water Preservation Technology can be Schematically Represented as Follows



Since tender coconut water is highly susceptible to heating, DFRL has standardized additives (bio-preservatives and non-nutritive sweetener) and their concentration; heating requirements for In-pack sterilization and suitable packaging systems (PET/PP and PET / aluminium foil / nylon / PP – stand-up pouches, Aluminum cans- 200 ml and 330 ml capacity with easy open ends and PP Bottles. TCW is subjected to minimum heating by the use of additives like nisin, a 'broad-spectrum' bacteriocin effective against many Gram-positive organisms, including lactic acid bacteria (commonly associated with spoilage), *Listeria monocytogenes* (a known pathogen), *Staphylococcus aureus*, *Bacillus cereus* and *Clostridium botulinum*, etc., to achieve commercial sterility.

5.2.2. Tender Coconut Water Ready to Serve Beverage Blended Fruit Juices

Tender coconut water has been blended with different fruit pulps, i.e., lemon, mango, pineapple, blue grapes, apple and pomegranate, etc., to increase the palatability as plain tender coconut water has bland taste. The products were found highly acceptable with a shelf life of nine months under packed conditions at ambient temperature. These products have gained a national status and have tremendous commercial potential.

5.2.3. Tender and Mature Coconut Water Beverage with Suspended Kernels (Lemon Flavoured)

Tender/mature coconut water beverage with and without suspended kernels has been developed as plain as well as in combination with lemon juice. The levels of lemon juice and Total soluble solids (TSS) were optimized. The product was found to be stable for six months under ambient storage conditions. The beverage was packed in standup pouches as well as in bottles. The kernels was treated to remain in suspended form as well as to avoid discolouration in the coconut water.

5.2.4. Preserved Mature Coconut Water Beverage

Mature coconut water beverage blended with lemon juice has been developed. The optimized beverage was packed in standi-packs showed a shelf life of 9 months under ambient conditions

5.2.5. Nata-De-Coco Bacterial Cellulose

Nata-De-Coco Bacterial cellulose produced by *Acetobacter xylinum* at the air liquid interface of coconut water is known as Nata-de-coco. *A. xylinum* uses the nutrients in the coconut water medium and forms a thin slimy, transparent layer of cellulose on the surface of the medium which thickens with age, forming a thick whitish sheet after fifteen to twenty days. This sheet is cut into cubes, washed and boiled in water before cooking in sugar syrup. This unconventional product based on coconut water has immense potential because of the increasing awareness of the health benefits of fiber rich products and the possibility of using a cheap, commonly wasted by-product of the coconut industry to make a commercially value added product with export potential.

5.2.6. Instant Coconut Chutney Mix

Coconut chutney provides a definite tang to many of the traditional south Indian delicacies such as idli, dosa, urad dal vada and bonda, etc. Without the seasoning effect of coconut chutney, many of these products stand to lose their traditional appeal. The RTE coconut chutney mix developed by DFRL contains coconut gratings, tamarind, green chilli, coriander leaves, ginger, salt, spices and oil besides curry leaves and mustard seeds as essential ingredients. The product reconstitutes almost instantly on addition of water.

5.2.7. Neera

Neera or toddy is also called as Kalparasa. Neera can be obtained by tapping unopened spadix (inflorescence) of coconut palm. Neera that drips out from the spade of coconut is a non-intoxicated, unadulterated, yummy flavoredsugar containing juice. Neera can arrest one's thirst and is projected to grow into king of soft drinks in future. Neera collection centre is easy to get started which is similar to milk centres. Neera is a healthy drink which contains 85% water, rest of which comprises sugar and proteins. The products such as jaggery, sugar and candy can be prepared from Toddy. Neera can easily be converted into value-added processed products such as jaggery, sugar, candy, ice cream and toffee, etc. There are technologies available (low cost and high cost) to preserve Neera for a period of 3 days to 2 months.

5.2.8. Virgin Coconut Oil (VCO) and VCO Meal based Products

Virgin coconut oil is a now a days coined as emerging functional food oil. The term VCO refers to an oil that is obtained from fresh, mature kernel of the coconut by mechanical or natural means, with or without the use of heat and

without undergoing chemical refining. VCO based Porridge was developed from VCO meal along with other ingredients like Skimmed Milk Powder, Sweet Potato Powder, Green Gram Powder, Carrot Powder and Gooseberry Powder, Pineapple Powder and Sugar Powder. The product showed excellent sensory characteristics. The product was found to be acceptable for a period of 8 months under ambient storage conditions.

6. Conclusions

We process only ~2.2% of the produce. In contrast, countries like USA (65%) and China (23%) are far ahead of India in reducing the wastage and enhancing the value addition and shelf life of the farm products. Higher the level of processing and proper marketing, better the post-harvest management and lower will be losses. Food processing industry (FPI) has been one of the largest and most prosperous sectors in terms of mass production practices, consumption, export and growth. FPI is a 250 billion dollar industry in India and contributes to 32% of the total value of food market in India and is currently growing at 10% per annum. The organised food business in India is worth US$ 48 billion. The Indian food processing industry accounts for 32 per cent of the country's total food market, one of the largest industries in India. It is ranked fifth in terms of production, consumption, export and expected growth. FPI serves as a vital link between the agriculture and manufacturing sectors of the economy. It creates 1.8 job directly and 6.4 indirectly/10000. Food Processing Sector is a non-recession sector aka as a sunshine or sunrise sector or a Goldmine. The earlier you enter Food Processing business, the more benefits you will reap. The Indian food retail market is expected to reach US$ 915 billion by 2020. We should strive to make India a world leader in food processing by giving impetus to the agricultural sector whose contribution has declined to a meager 14% to the GDP. This is also in consonance with the vision of our Hon'ble PM of doubling farmer's income by 2022 (end of XIII FYP. 75th year of Independence), given at Bareilly on 28 Feb 2016. Indian Food processing industries should contribute to the eco-sustainable development of the food processing protocols that effectively manages the energy and water use by effectively embracing novel and innovative technologies. They should also adopt technologies to reduce the food losses / wastage and improved utilisation of unconventional resources available in the country. Although the direct eco-impact of food processing is rather small compared to primary agro-food production, still substantial savings can be achieved by adopting many innovative processing technologies that give major efficiency improvements compared to traditional

technologies. FPI sector is identified as one of the priority sectors by the GOI under the national manufacturing policy. FPI is one of the 25 sectors identified under the Make-in-India programme where the government is making plans to attract both domestic as well as foreign investment. As per Department of Industrial Policy and Promotion (DIPP), the food processing sector is one of the top 15 sectors where India has been receiving significant Foreign Direct Investment (FDI). According to the Department for Promotion of Industry and Internal Trade (DPIIT), the Indian food processing industry has cumulatively attracted Foreign Direct Investment (FDI) equity inflow of about US$ 8.57 billion between April 2000 and December 2018.

R&D effort by DFRL has helped in developing technologies to extend the shelf-life of a variety of traditional food products of Indian dietary matching the main frame palate/taste of India. Some of the simple technologies could be easily taken up by small and medium scale industries. Worldwide there is a great demand of technologies, processes and products developed by DFRL.

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