REPORT

Value Addition to Agriculture Through Food Processing

Science, Technology, Benefits

ILSI India

International Life Sciences Institute-India

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www.ilsi-india.org

ILSI-India is an entity of the International Life Sciences Institute (ILSI), headquartered in Washington DC. ILSIIndia provides scientific inputs and secretariat assistance to the South Asian Region, which includes Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

ILSI-India activities primarily focus on local and regional issues and involve leading national and international experts in the deliberations. ILSIIndia is the leader in the region in focusing attention and devoting resources on critical areas in food and water safety, nutrition, risk assessment, harmonization of food regulations, improvement in the health profile of malnourished children and women, and agriculture sustainability including biotechnology. Special attention is given to the importance of complementary foods and food fortification.

ILSI-India carries out its mission through sponsoring workshops, symposia, conferences, seminars, training programs, research projects, and publications.

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Founded in 1978, ILSI is a non-profit, worldwide organization whose mission is to provide science that improves human health and well-being and safeguards the environment. ILSI entities design programs to foster multi-sector collaboration conducting, summarizing, and disseminating science related to the world's most pressing health issues. ILSI strategy encourages global action on identifying and then resolving outstanding scientific questions in four thematic areas that capture the core of ILSI's work:

- **Food Safety**
- **Risk Science and Toxicology**
- **Nutrition and Health**
- **Sustainable Agriculture and Nutrition Security**

These focus areas provide structure for responding to and raising awareness of the pressing issues society faces. They also help elucidate new opportunities for driving scientific progress. ***ILSI's work is guided by its Code of Ethics, Scientific Integrity and Organizational Standards of Conduct.***

ILSI accomplishes this work through its **worldwide network** of ILSI Entities: Argentina, Brasil, Europe, Focal Point in China, India, Japan, Korea, Mesoamerica, Mexico, Middle East, North America, North Andean, South Africa, South Andean, Southeast Asia Region, and Taiwan and Research Foundation. ILSI's scientific publications are duly recognized all over the world. They include the journal *Nutrition Reviews* and the book Present Knowledge in Nutrition. Please visit www.ilsi.org for more information on ILSI and its network.

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Introduction

ILSI-India organized a Seminar on "Value Addition to Agriculture through Food Processing: Science, Technology, Benefits" on April 26 in New Delhi. The Seminar was organized against the fact that India has a large agrarian base and is one of the largest producer of cereals, fruits, vegetables and milk in the world. However, produce worth INR 92,000 crores is wasted due to lack of adequate food processing capacity in the country. At the same time the country faces the dual burden of micronutrient malnutrition and overweight and obesity.

The objectives of organizing this seminar were to:

- Look at strategy to check food losses for providing food and nutrition security in general and discuss the benefits of processing agricultural and horticulture products in particular.
- Examine the potential benefits and accompanying challenges of the latest new technologies to create new foods and ingredients keeping in view the health profile of the population and changing lifestyle.
- Explore the innovations in taste technology, computational gastronomy and its applicability as also development of new products including plant based, cell based novel products.

Brief Report on Proceedings, Key Findings and Recomendations are given in the following sections.

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Key Findings

Post-Harvest Losses

- The benefit of India's large agrarian base remains untapped due to inadequate processing facilities and infrastructure. The processing of cereals and fruits and vegetables is quite low (1%-2%) . The post-harvest losses are quite huge. According to a report on "Assessment of Quantitative Harvest and Post-harvest Losses of Major Crops and Commodities in India" by CIPHET the wastage is almost INR 920 billion (USD 13 billion) per annum.
- Such losses have implications for other associated losses. For example, wastage of a kilogram of rice and wheat leads to water wastage of 3500 liters and 1500 liters of freshwater that goes into their production respectively.

Malnutrition

- Despite rapid economic growth and Food Security, hunger and poverty still persist in India. India houses 25% hungry and poor population of the world! Enough food availability does not translate to access of sufficient nutrition. More than 70% of Indian population consume less than 50% of the RDA of micronutrients. Food wastage is a significant contributor to malnourishment and hunger.

Food Processing

- Food processing industries help in checking post-harvest losses, provide food and nutrition security, allow enjoyment of food over longer shelf life. enable consumers across the world to enjoy foods sourced from anywhere, ensure safety of food products and empower women as they have to spend less time on cooking. It is possible to address some of the health issues like malnutrition, celiac disease, IBS etc. through processed foods.
- The size of food processing industry is about INR 5.1 trillion and it is growing at the rate of about 17.8%. However, the share of processed food industry in total food consumption in India is 32% only. With change in lifestyle this is likely to go up.
- Product innovation will be the key to expansion with change in consumer's taste, demand for use of healthier ingredients as also frozen products and sensible snacking.

New Food Processing Technologies and Impact on Quality, Nutrient Contents and Environment

- There has been advancements in use of food processing technologies. However, if appropriate technologies are not used it may lead to loss in nutrients and affect the organoleptic quality of foods.
- Important characteristics of the food that determines the marketability of the products, such as appearance, texture, taste and nutritional content are strongly influenced by the method used for processing foods. Some of the non-thermal food technologies like High Hydrostatic Pressure Technology and Pulsed Electric Field (PEF) Processing Technology have the advantages of enhancing the safety, quality, nutritional, and functional properties of foods with minimal deleterious effects on their nutritional and organoleptic characteristics. A combination of processing technologies can be used for higher benefits.
- The global demand for protein is increasing . There could be tremendous adverse implications world over in the next decades.
- Conventional animal agriculture poses substantial threats to human health, the environment, and animal welfare. It is a leading cause of environmental destruction – including deforestation, ocean dead zones, and water and

air pollution – and contributes more greenhouse gas emissions than the entire global transportation sector.

- Two of the most promising solutions to meet growing global protein demand are plant-based meat and cell-based meat: using plant-based ingredients and animal cells as more sustainable inputs and units of production.
- 'Computational Gastronomy' has facilitated creation of Culinary Fingerprints which enable tracing the origins of a recipe, can be used in providing advice on personalized nutrition as also designing novel food beverages and recreating ancient foods.
- Technologies have been developed for reducing sugar and salt in food and beverages. While products providing umami flavor can be used to reduce salt while still retaining the taste, high intensity sweeteners can be used as substitutes for sugar

Recommendations

- There is a need to move from "Self Sufficient and Enough Quantity Food Security" (SQ) to "Sufficient Quantity and Safe Quality Food and Nutritional Security" (2S-2Q).
- Strong infrastructure and adequate food processing facility are essential for checking post harvest losses and providing food and nutrition security. It is also important to build links between farm and industry.
- A "National Mission on Food Processing" should be set up to formulate suitable policies for development of food processing industries.
- There is a need to create awareness in public about benefits of processed foods.
- Innovations in food processing technologies have paved the way for use of technologies with minimum / no impact on nutrient contents and organoleptic qualities. Such technologies should be used by the industry.
- R&D in taste technology have led to development of sugar and salt substitutes. They can be used to replace/reduce sugar and salt in product formulation without affecting taste.
- R&D in cell based and plant based meat should be expedited to meet the rising demand for protein in the country. In order to advance the research and commercialization of plant-based and cell-based meat to accelerate the transition to a better food system, the critical technology elements of each of these foods must be analyzed and further improved.
- The 19 ancient scriptures of India like "CharakaSamhita" should be referred for studies on Indian cuisine and to build data base .
- The science of Computational Gastronomy can be used for personalized nutrition advice, creating new products and tracing origins of recipes.
- Safety of new products should be ensured by following safety protocols including risk assessment.
- Lifecycle assessment of new products like plant based proteins should be undertaken to study benefits.

Section One
Opening Session

Welcome Address
Prof. P. K. Seth, Chairman, ILSI-India

India is leading producer of many agricultural and horticulture commodities: the second largest producer of fruits and vegetables, rice, wheat and many other cereals in the world. Overall it is the third largest producer of agricultural produce in the world be it plant based, animal or poultry based or marine based products. Third after China and USA.

The benefits of the large agrarian base that India has remains untapped due to inadequate processing facilities and infrastructure. The post-harvest losses are quite huge. According to a report on **Assessment of Quantitative Harvest and Post-harvest Losses of Major Crops and Commodities in India** by CIPHET the wastage is almost INR 920 billion (USD 13 billion) per annum.CIPHET is Central Institute of Post Harvest Technology, Engineering and Technology of Indian Council of Agricultural Research of Ministry of Agriculture.

The highest loss is of cereals. Cereals worth Rs. 20,700 crores are lost. The second and third highest losses are in fruits and vegetables. Losses stand at Rs 16, 650 crores and INR 14, 850 crores respectively. These estimates are for production year 2012-13. The CIPHET report strongly recommends investing resources on storage and post-harvest processing and value addition. A grain saved is a grain produced.

It is important that foods produced should be processed to check food losses and provide food and nutrition security. Many foods, which are consumed every day have to undergo processing at the primary level such as wheat to wheat flour, oilseeds into edible oils, sugarcane into sugar etc. Such products are then used for making items that have to be consumed at household level as well as on a large scale at industrial level or in restaurants. Foods are also processed to extend the shelf life of foods and improve availability.

In the current global scenario processed packaged foods have a role. The benefits range from checking post-harvest losses, providing food and nutrition security, allowing enjoyment of food over longer shelf life, enabling consumers across the world to enjoy foods from anywhere, ensuring safety of food products, empowering women as they have to spend less time on cooking. Checking post-harvest losses and strengthening food security are major benefits. It is possible to address some of the health issues through processed foods- from pediatrics to geriatrics. For example, technology has made it possible to address micronutrient malnutrition problem through food fortification.

The latest research on Gut Microbiome shows that an unhealthy microbiome can contribute towards increased susceptibility to infection as well as to NCD's like obesity, metabolic syndrome and allergy and inflammatory diseases. Research institutions both from public and private sector, therefore, are devoting attention to how diet can rehabilitate the gut ecosystem. While research can show the way industry has to carry the benefits of research to masses through addition of probiotics and prebiotics to processed products. People suffering from celiac disease can have gluten free products.

Keeping in view the close link between agriculture and food processing and the various benefits Government set up Ministry of Food Processing Industries to promote development of food processing industries.The Government has also created a number of institution functioning under different Ministries like: CSIR ITRC, CFTRI, DBT, THSTI, NCCS, NIFTEM , ICMR, NIN and IIP to promote safe, nutritious and healthy products and ingredients. It has also established a strong regulatory framework to provide guidance on safe foods, monitors their implementation and protect consumers interest. FSSAI and EIC have been working towards providing safe and nutritious foods to both domestic and international consumers.

The size of food processing industry is about Rs 5.1 trillion and it is growing at the rate of about 17.8% However, the share of processed food industry in total food consumption in India is 32% only. With change in lifestyle this is likely to go up. ILSI-India considers it essential that food and beverage that are offered to consumers are healthy and nutritious. For this to happen it is crucial that food processing industries develop on scientific lines and provide healthier options to consumers.

In order to ensure that ILSI-India has organized several scientific meetings, conducted training programs and sponsored research along with Government and R&D organizations on issues relating to food and nutrition security, healthy aging, bone health, gut health, nutrition and HIV AIDS, food safety, risk assessment, new food technologies, new plant breeding technologies, micronutrient fortification of foods, packaging, sugar and fats, type2 diabetes, vitamin D, growth velocity of children etc.

Only one third of total food consumed in the country is supplied by the industry. Almost two-third is prepared at home. Hence, there is a need to create awareness in the population about healthy eating and how to prepare healthy food at home. ILSI-India has prepared a booklet for dissemination of information to general public. This is called “Eating Right for Healthy You”. It is science based but prepared in simple language.

Key Note Address

Dr. Chindi Vasudevappa, Vice Chancellor, National Institute of Food Technology Entrepreneurship and Management (NIFTEM), MoFPI

“Agriculture, Animal husbandry, and Aquatic (AAA)” sectors – are key drivers for national growth – resulting in self sufficiency in food production. India has many natural advantages in the agriculture sector. Arable land in India is 52% as against global average of 11%. It has 46 different soil verities out of 60 found in the world. It has a number of agro-climatic zones and is suitable for cultivation throughout the year.

The country has largest livestock population (300m) in the world, is the largest milk producer (Milk production is 167 MMT) and is the largest grain producer (Grain production -285 MMT). It is the second-largest producer of fruits and vegetable (305 MMT) and aquaculture production (6.8 MMT) and is one of the top six producers of rice, wheat, groundnuts, tea, coffee, tobacco, spices, sugar and oilseeds.The country has had four Agro-Food Revolutions: Green, White , Blue and Pink. The agro food sector has grown from 43% to 203% between 2001and 2017 ***(Appendix-1).***

The processing of agro-food is quite low (1%-2%) except for meat products ***(Appendix-2).*** The post harvest losses due to lack of processing facility and other problems is quite high as estimated by CIPHET and FAO–Table 1. According to CIPHET food loss is about INR 92,000 crores.

Table 1: Food Loss and Waste in Food Supply Chain

Commodity	Agri Prod.	PH. Storage & Handlimg	Processing & packaging	Distri-buting	Consump-tion	Total (As per FAO)	PH Loss % (CIPHET)
Cereals	6	7	4	2	3	22	4.5-6
Onion & Potato	6	19	10	11	3	49	7.3-8.2
Oilseed & Pulses	7	12	8	2	1	30	3-10
Fruits & Vegetable	15	9	25	10	7	66	6.7-15.5
Milk							0.92
Meat (Goat & Sheep)							2.71
Poultry							6
Fish							11

Source: Key Note Address by Dr. Chindi Vasudevappa

A report in CSR journal says "Indians waste as much food as the whole of United Kingdom consumes". According to FAO, one-third of total global food production is wasted annually. Globally 1.4 billion hectares of land is devoted to producing food that is ultimately lost. It is an irony that there are huge food losses, one out of every nine persons in the world is starving. Thus food wastage is a significant contributor to malnourishment and hunger. It also has implications for other associated losses. For example wasting a kilogram of rice and wheat leads to water wastage of 3500 and 1500 liters of freshwater that goes into their production respectively.

Food Security v/s Nutritional Security – India's case

Despite rapid economic growth and food security, hunger and poverty still persist in India. India houses 25% hungry and poor population of the world! Enough food availability does not translate to access of sufficient nutrition. More than 70% of Indian population consume less than 50% of the RDA of micronutrients. About 6000 children die due to malnutrition and lack of micronutrients. Malnutrition problems are more prominent in rural populations. The following data on nutritional status and health of children are alarming:

- 38 % of children below five years (urban: 31%, rural: 41%) are stunted (low height for age)
- 21% (urban: 20%, rural: 22%) are wasted (low weight for height)
- 36% (urban: 29%, rural: 38%) are underweight (low weight for age)
- 2% are overweight (above normal weight for height)
- 58 % of children aged between 6 and 59 months (urban: 56%, rural: 59%) are anemic.

There is a need to move from"Self Sufficient and Enough Quantity Food Security"(SQ) to "Sufficient Quantity and Safe Quality Food and Nutritional Security" (2S-2Q).

Role of Science and Novel Technologies in Food Processing and Benefits

The new agro-food processing technologies are revolutionizing the way food is produced and have paved the way for production of healthier products. Some of them are: Cold plasma technology, Pulsed electrified field and Ohmic heating, Irradiation (Few studies have observed increased vitamin C content of irradiated citrus fruits), Hydrolysis of bio-waste/protein rich foods, High-pressure (HP) processing, high-pressure homogenization (HPH), Ultrasonication, Three-dimensional printing (3DP) process, GM/GE technology etc.

The technological developments have allowed industry to produce many value added products such as: frozen, ready to eat, extruded products, and

fortified products. Developments in packaging technology has facilitated providing all food products including traditional foods in packaged form.

Food industry is a diversified, high growth and high profit sector. It contributes to 32% of India's total food market. India's grocery and food market ranks 6th in the world. It contributes 8.8% of Gross Value Added in manufacturing sector. Agro food processing Industry employs 18% of country's industrial work force. It accounts for 6% of total industrial investment.

Trends in Food Consumption

- Food consumption is on a consistent rise. It grew at CAGR of 11.6% [INR 25,81,279 crore (US $403.3 billion)] during 2015-16.
- In 2017 – food retail market (excluding non-food grocery) was estimated at INR 35,38,282 crore (US $552.86 billion) .
- Consumption in FG segment grew at a CAGR of 12.1 – 90% and in FS segment at 7.2-10%.
- Growth in 2020 is estimated at a CAGR of 14.4%. Market will grow to a size of INR 53,05,488 crore (US $828.98 billion^) in 2020.
- As regards organized food service retail, the share of large metro-cities is quite high: Delhi and Mumbai together are estimated to have market share of over 20%. Six metros of Pune, Ahmedabad, Bengaluru, Hyderabad, Chennai and Kolkata, together have 20% share. Balance is shared by other Tier I and II cities spread across the country.
- Eating out culture as a way of life is increasing in India with huge scope for multiple cuisines and related services.
- Demand for Indian product in international market is increasing.
- Product innovation will be the key to expansion with change in consumer's taste, demand for use of healthier ingredients as also frozen products and sensible snacking.
- Indian gourmet food market is valued at $1.3 billion and is growing at CAGR of 20%.
- Demand for organic food is increasing and the organic food business is expected to increase by 3 times.

Strategy for Providing Food and Nutrition Security

Providing food and nutrition security to 1.5 billion by 2020 requires work on multiple fronts:

- Organizing marginalized and unorganized farm sectors towards ensuring production of safe produce.
- Creation of backward and forward linkages between agriculture and industry.
- Bringing innovations in technology.
- Strengthening infrastructure: establishing integrated cold chain, improving supply chain and quality assurance infrastructure .
- Formulating suitable food safety regulations.
- Providing training in entrepreneurship development and skill development .
- Extending financial support and incentives to private sector.
- Promoting rationalization of tariff and duties.
- Setting up of National Mission on Food Processing.
- Creating/ Expanding processing/ preservation capacity and agro processing clusters.
- Creating awareness about benefits of processed foods and larger investments in this sector.

Section Two

Technical Session

Chair: Prof. P K Seth, Chairman, ILSI-India

Innovations in Food Processing Technologies: Impact on Nutrient Composition & Food Safety

Dr. N M Sachindra, Chief Scientist, Department of Meat & Marine Sciences
CSIR-Central Food Technological Research Institute, Mysore

Food industry always focuses on the market trends and the consumer needs and orients itself towards achieving targets like safety of the product and providing good shelf life to the product. Consumers are more aware now with respect to nutritional quality of the food products and look for health benefits associated with a food product. In addition to nutritive quality of the food, sensory quality is also an important criteria considered by the consumers and they expect a food product to be chemical free.

The demand for convenience products is increasing due to change in the life style. The food industry should be able to provide the products at affordable price. In addition to the consumer needs the food industry should meet consumer expectations and should also be concerned about the societal needs like the environmental impact of the industry and carbon foot print and waste generation. There is always the issue of rising cost of raw material which may off balance the economics of the food industry.

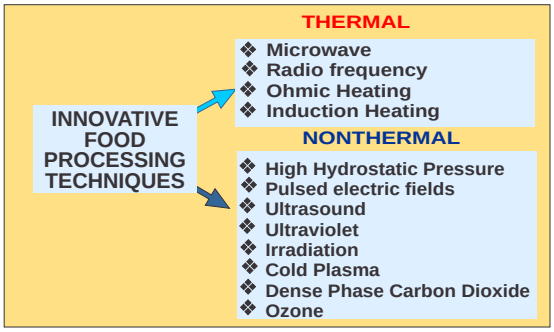
With change in market demands and consumer needs, the industry is always looking for new and innovative technologies in food processing. It traditionally used thermal processing technologies, where the food products are subjected to high heat to achieve safety and improve shelf life of the product. However, it has the disadvantage of inducing flavor and nutrient loss and bring about change in the physico-chemical properties of the food product.

An ideal food processing technique should have features like: inducing minimum loss of sensory and nutritional quality and at the same time improving the safety and shelf life of the product, have lower temperature of operation, create less impact on environment and should be low cost. There are a number of innovative food processing techniques using both thermal and non-thermal methods.

Important characteristics of the food that determines the marketability of the products, such as appearance, texture, taste and nutritional content are strongly influenced by the methods used for food processing. Consumer awareness about good nutrition along with the increasing demand for fresher tasting foods have paved the way for new food processing technologies. These include:

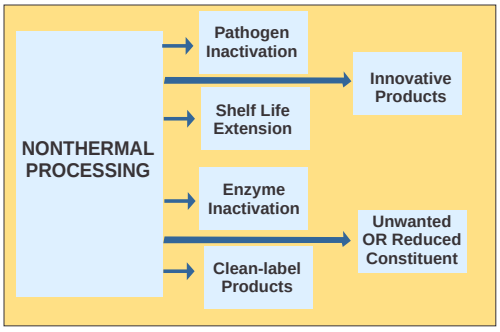
- **Thermal processing methods** such as microwave (MW), radio frequency (RF), infrared (IR) heating, pressure-assisted thermal sterilization (PATS), and sous-vide processing (SVP).
- **Non-thermal methods** such as high hydrostatic pressure (HHP) processing, irradiation, ultrasound, pulsed electric field (PEF), and pulsed light (PL) technologies.

Figure 1: Innovative Food Processing Technologies



Source: Presentation on Innovations in Food Processing Technologies: Impact on Nutrient Composition & Food Safety by Dr. N M Sachindra

Figure 2: Benefits of Non-Thermal Processing Technologies



Source: Presentation on Innovations in Food Processing Technologies: Impact on Nutrient Composition & Food Safety by Dr. N M Sachindra

Non Thermal Processing Technologies

High Hydrostatic Pressure (HHP): Among the non-thermal processing technologies HHP has been explored by food research institutions as well as the food industry with the goal of enhancing the safety, quality, nutritional, and functional properties of foods with minimal deleterious effects on their nutritional and organoleptic characteristics. In HHP processing, foods are exposed to the pressures of 200–1000 MPa for a few minutes using a suitable pressure-transmitting fluid such as water. HHP relies on the isostatic principle, wherein the food product is compressed instantaneously and uniformly from every direction and returns to its original shape when the pressure is removed. The negative effect of HHP processing on quality of food has been found to be minimal.

High Presure Technology (HPT) can be used as alternative to thermal processing and use of preservatives in food preservation. The preservation mechanism of HPT is similar to high temperature, where the microorganisms are killed due to permeability of cell membrane. These changes are reversible at low pressure, but irreversible at high pressure. High pressure also reduces the enzyme activity. And as high pressure affects only the covalent bonds, the changes in organoleptic properties are minimum.

The main advantage of HPT is that the food can be processed at ambient or even at low temperature. As this technique enables the transmittance of the pressure uniformly throughout the system irrespective of the size and shape of the food the size reduction may not be required. This is a chemical free process and improves the overall quality of food. As HPT can alter gel forming ability of some proteins, this technique can also be used to create food ingredients with unique properties.

Food that can be HP treated include:

- Solid foods, mainly vacuum packed;
  - Dry-cured or cooked meat products
  - Cheeses, Fish, seafood, marinated products
  - Ready to eat meals, sauces
  - Fruits, marmalades / jams, Vegetables
- Liquid foods, in flexible packaging
  - Dairy products
  - Fruit juices
  - Nutraceutical formulations

Food that cannot be HP treated are:

- Solid foods with air included: Bread, Mousse
- Packaged foods in completely rigid packaging: In glass or canned
- Foods with a very low water content: Spices, Dry fruits

HPT affects the physioco-chemical properties of some foods. For examplein fresh or marinated meat the red color is lost as iron in the mysoglobin changes from ferrous to ferric form and the globin is denatured. However, no such color changes are observed in cooked meat and fruit juices and no alternations in flavor is observed. High pressure may cause slight softening of texture and reversible crystallization of fats.

UV-C Light Technology:The application of UV-C light technology for food products has been mainly confined to liquid foods and water. Deleterious effects of UV-C processing are surface discoloration, accelerated senescence or sprouting. UV radiation may also denature proteins, enzymes, and aromatic amino acids, leading to changes in the composition of the food material. Exposure to UV light can change the flavor profile in certain products.

Pulsed Light (PL) Technology: Pulsed light (PL) technology is a method for the decontamination and sterilization of foods using very high-power and very short-duration pulses of light emitted by inert gas flash lamps. The lethal effect is due to combination of action of light pulses on certain cell constituents such as proteins and nucleic acids.

As these light pulses are of short duration and high energy, PL can achieve effective microbial inactivation without any major adverse effect on product properties. Pulsed light treatment of food applied at high doses can negatively affect the sensory and nutritional quality of foods with surface discoloration, loss of vitamins and other pigment compounds, as well as textural changes.

Pulsed Electric Field (PEF) Processing:Pulsed electric field is a new emerging food processing technology. In this techniques, food is subjected to high voltage in short bursts, that is in short pulses of microseconds. High voltage in short pulses destroys the microorganism by damaging the cell membranes, inactivates the enzymes without affecting the nutritional quality of food. PEF processing involves the application of high-voltage pulses to foods located between a series of electrode pairs. The anti-microbial efficacy of the PEF process varies as a function of numerous processing parameters, including the electric field strength, number of pulses, pulse duration, pulse shape, processing temperature, and physiological state of the microorganisms. Other factors that influence the degree of inactivation include the temperature of the food, pH, ionic strength, and electrical conductivity.

This technique uses low processing temperature and short time, thus it is energy efficient and at the same time, minimizes the loss of food quality. It avoids or reduces the detrimental changes of the sensory and physical properties. Wide application ranges from increasing the efficiency of the process to food preservation processes. It is most ideal for heat sensitive fluid foods; Non fluid food and food containing particles can also be processed. Continuous application and the short processing time makes it an attractive candidate as a novel non-thermal unit operation. Still substantial research and development activities are required to understand, optimize and apply this complex process to its full potential.

Ultrasound Technique for Food Processing: Ultrasound technique is a novel food processing technique. Ultrasonic waves have the ability to influence the biochemical and microbiological properties of food. The lethal effect of ultrasound is mainly due to disruption of cell membrane, localized heating and free radical production. There are a

number of applications of ultrasound in food industry like, inactivation of microorganisms and enzymes, degassing , extraction, homogenization, meat tenderization and so on.

Application of Ozone in Food Processing: Ozone processing of liquid food is a non-thermal method of processing. Ozone is active against bacteria, fungi, viruses, protozoa, and bacterial and fungal spores pertinent to fruits and vegetables and their products. The main advantage of ozone processing is that, it is a powerful antimicrobial agent. Its reaction with organic materials is faster than chlorine and there are very few decomposition products. It leaves no residues in food, as it easily decomposes to oxygen in short time. However, ozone may induce some color changes in fruit juices. Ozone treatment reduces the microbial load considerably in sugarcane juice, and also inhibits the activities of the enzymes like polyphenol oxidase and peroxidases which cause browning.

The efficacy of ozone treatment can be further enhanced by combined treatment with ultrasound. Ultrasound increases the surface area and thereby enhances the effect of ozone. Ultrasound treatment also makes the microorganism more sensitive to ozone treatment.

NEW Initiatives at CSIR-CFTRI

- High pressure processing of fruit juices
- Application of ozone for decontamination of fruit juice
- Non-aqueous application of membrane technology - extraction and refining of edible oils which will eventually result in big energy savings in vegetable oil refining industries
- Advanced drying techniques - EMR based process for improved quality and energy savings
- IR Drying of cashews - Reduced processing time, higher yield of whole kernels, improved whiteness
- Hybrid drying – IR and Hot air/microwave and hot air – Reduced processing time (30-40%); energy efficient (30-40% saving)
- Enzyme inactivation – alternative to hot water blanching – retaining the water soluble nutrients
- Smart Packaging - spoilage indicators, self-heating/cooling pouches
- Vacuum Frying System - low fat snacks with better health benefits
- Low Glycemic products, gluten free products, millet based products
- Natural antimicrobial compounds as food preservatives
- Natural food protectants
- Plant based meat alternatives
- Prebiotics & probiotics, nutraceuticals, natural flavors and colors
- Super foods – Quinoa, chia, teff, spirulina
- Specialty foods – anti-cancerous, antidiuretic
- Omega-3 fatty acid from new sources – Microbial, plants (Chia, Portulaca, Buglossoides)

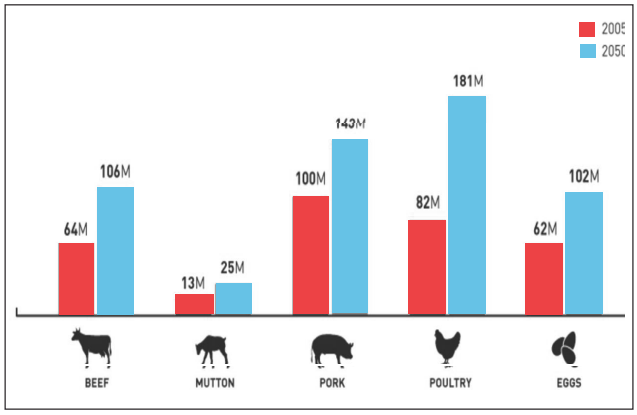
In the quest for better quality, more nutritious, minimally processed, and safer foods, these innovative technologies have become the subject of intense research, furthering expansion of the knowledge base is taking place and there is a good scope for commercialization of these techniques.

Case Study on New Technologies and Their Challenges

Mr. Varun Deshpande, Managing Director, Good Food Institute (GFI)

With the world's population set to hit 10 billion by 2050, one of the most pressing current challenges is the creation of a global food system which does not have negative consequences for the planet, for scarce natural resources, and for human health. This is made all the more urgent by the growth in demand for protein, Rise in poultry demand driven by higher incomes in emerging markets – India and China will play the biggest role.. There could be tremendous adverse implications for the world over the next decades.

Figure-4: Trends in Global Demand for Meat



Source: Food are Agriculture Organization of the United Nation USA Working Paper No. 12-03 /131 Presented by Mr Varun Deshpandey, GFI

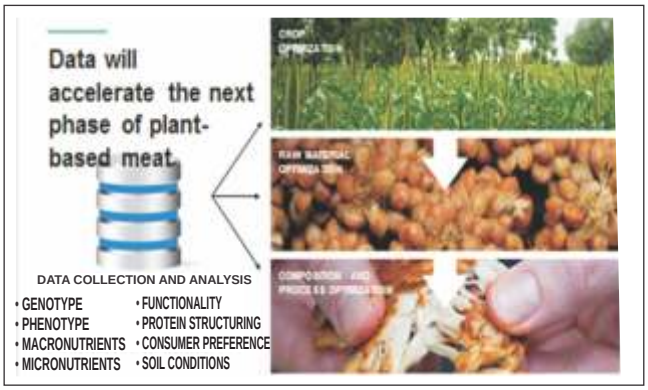
The intensification of industrial animal agriculture to produce meat, eggs, and dairy has thus far failed to provide a viable solution. Conventional animal agriculture poses substantial threats to human health, the environment, and animal welfare. It is a leading cause of environmental destruction – including deforestation, ocean dead zones, and water and air pollution – and contributes more greenhouse gas emissions than the entire global transportation sector. It also creates significant public health threats from antibiotic resistance and zoonotic disease epidemics, as well as acute consumer risk in the form of foodborne illness from fecal contamination introduced during slaughter and rendering. And above all, animals are inefficient production systems for protein, with input-output ratios which place significant strain on the planet. An inefficient food system is of particular concern in India, where food insecurity and poor nutritional status are especially severe.

As consumer concerns over the implications of industrial animal agriculture continue to mount, the application of science and technology to remaking animal products is an imperative. There are two solutions:

1. Plant-Based Meat and
2. Cell-Based Meat

Plant-Based Meat: Plant-based and cell-based meat represent an opportunity to significantly alleviate the burdens of the entrenched food system. Plant-based meats are made entirely from crops and plant-based ingredients. Plant-based meat products are structured plant- or fungus-derived foods designed to replace animal-based meat either as stand-alone products or within recipes.They look, taste, and feel like conventional meat from animals. Data will accelerate the next phase of plant-based meat.

Figure-5: Data Collection & Analysis of Plant Based Meat



Source: Case Study on New Technologies and Their Challenges by Mr Varun Deshpandey

Cell-Based Meat: Cell-based meatis also called 'clean meat'. It utilizes the methods of cell culture to grow animal meat outside of the animal. Cell-based meat is genuine animal meat that can replicate the sensory and nutritional profile of conventionally produced meat because it is comprised of the same cell types arranged in the same three-dimensional structure as animal muscle. A cell line has to be developed using a strain of animal cells that can be reproduced in cell culture (in vitro). . Scientists are now trying to understand which are the most efficient cell types for clean meat products.

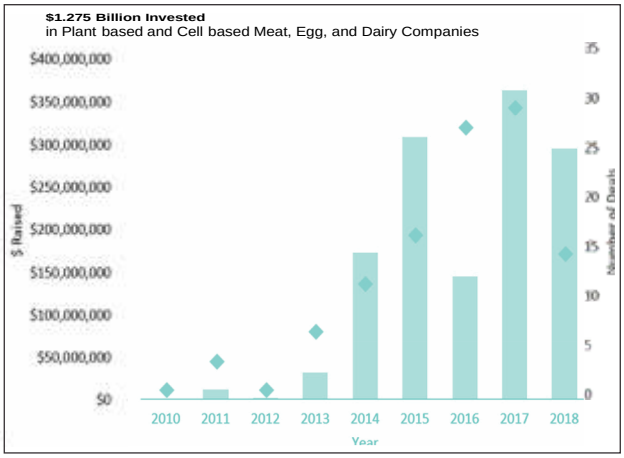
Once the best cell type is identified, the appropriate combination of nutrients have to be used to grow the cells. Cell culture media is a combination of vitamins, minerals, salts, sugars and amino acids. It also contains molecules of cell growth factors that can keep cells in a proliferation stage or cause them to differentiate.

Scientists use FBS or fetal bovine serum to grow cells for clean meat. This is a common practice in basic research labs but is rarely used in large scale manufacturing. As the clean meat companies scale and move towards commercial products, they will eliminate the use of FBS in cell culture media. Cell culture media is currently the largest cost barrier to creating clean meat at a price that is competitive with conventional meat. However, an analyses by GFI indicates that once the formulations are optimized, the industry sources raw materials that are manufactured and priced for the food industry, and as the amount of media used by the industry scales, the costs will decrease significantly.

The volumes of media required to produce enough clean meat to satisfy future market demand will be several fold more than what is currently required by the pharmaceutical industry.

These categories of food are receiving plaudits from organizations such as the United Nations and millions in investment from visionary investors.

Figure-6: Investments in Plant Based and Cell Based Meat



Source: Crunchbase; YTD as of 8/18
Presented by Mr Varun Deshpandey, GFI

In order to facilitate commercialization of plant-based and cell-based meat the critical technology elements of each of these foods must be analyzed and further improved. Within plant-based meat, the sourcing of the raw materials, the processing and formulation of the product, the eventual marketing and distribution are important. In cell-based meat, the critical technology elements include cell lines, scaffolds, cell culture media, and bioreactor design. Investment and advancement in each of these areas would have a significant impact on the future of food and the ability to sustainably feed the growing population. India has a huge role to play in this transformation, and stands to benefit by pioneering the work on affordable protein to close nutritional gaps.

Key Takeaways

- New technologies are unlocking opportunities to develop the next generation of meat using more sustainable production methods.
- Two of the most promising solutions to meet growing global protein demand are plant-based meat and cell-based meat: using plant-based ingredients and animal cells as more sustainable inputs and units of production.
- While the alternative protein field has garnered buy-in from notable industry incumbents and investors, there is still substantial room for innovation to advance plant-based and cell-based meat products.

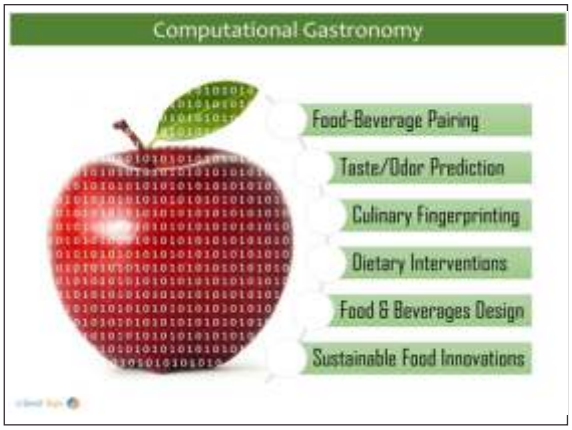
Computational Gastronomy: The Emerging Data Science of Food, Flavors, and Health

Dr. Ganesh Bagler, Assistant Professor, Complex Systems Laboratory, IIIT-Delhi

Cooking forms the core of the cultural identity other than being the basis of nutrition and health. Starting with a seemingly simple question, 'Why do we eat what we eat?', data-driven research conducted in IIITD lab has led to interesting explorations of patterns in traditional recipes, their flavor composition, and health associations. The investigations have revealed 'culinary fingerprints' of regional cuisines across the world, starting with the case study of Indian cuisine.

Increasing availability of culinary data and the advent of computational methods for their scrutiny is dramatically changing the artistic outlook towards gastronomy. Application of data-driven strategies for investigating the gastronomic data (such as traditional recipes, molecular constituents of ingredients, percepts of flavor compounds, and health associations of food) has opened up exciting avenues giving rise to an all-new field of 'Computational Gastronomy'.

Figure-7: Computational Gastronomy



Source: Presentation on Computational Gastronomy by Dr Gansh Bagler

Computational gastronomy is the study of ingredients, and how and why they are used with one another, where each ingredient "becomes a bowl of flavor molecules". It is looking at food as not just art, craft and skill, but also as a science. It brings together data scientists and researchers, chefs, nutritionists, agriculturists, and people from the food industry, with the opportunity to bring about synergies.

This emerging interdisciplinary science asks questions about culinary origin and seek their answers via compilation of culinary data and their analysis using statistics, machine learning, natural language processing, pattern mining, and chemo-informatics. Along with complementary experimental studies, it has the potential to transform the food landscape by effectively leveraging data-driven food innovations for better health and nutrition.

Food pairing is at the core of the work. Food pairing specifies how flavor molecules are shared among all pairs of ingredients and is the way in which ingredients are put together. It gives a measurable number. A review of food pairing has shown that food pairing pattern of cuisine in India is uniquely different from Western cuisine. While Indian food has contrasting food pairing (combining flavors that are not similar to each other in a dish, for example, tamarind and jaggery together in making a dish), Western cuisine is based on complementary or uniform food pairing (flavors in a dish close to each other). Spices particularly hold a unique position in the food pairing pattern observed in the Indian cuisine.

Like DNA fingerprint, Culinary fingerprints of various world cuisines have been created using flavor molecules and ingredients. The fingerprint characterizes the cuisine, highlighting its idiosyncratic patterns. The work

is on for generating novel recipes by exploring these patterns. The Complex Systems Laboratory has compiled information on recipes and ingredients from 24 world regions and 71 countries. They have been broken down into ingredients and flavor molecules and the data is also made available as an Android App. Novel recipe generation algorithms of recipes are being developed. The association between dietary ingredients and their health impact has been compiled from PubMed and Medline databases. The computational gastronomy framework can be implemented for effective personalized nutrition.

Innovations in Taste Technology for Health Benefit

Ms. Alka Agarwal, Senior Manager, Givaudan (India) Pvt. Ltd

Sweetness Enhancement/ Sugar Reduction

Flavor Houses are investing in creating fundamental knowledge of sweet taste and a pallet of unique ingredients. Some foundational work in Ingredient Discovery is fueled by taste receptor research, ground-breaking sensory measurements of sweet taste, and new processing techniques. To bring new sweet taste discoveries to life, organizations should have expert regulatory support and investment in ingredient scalability and manufacturing that turn great potential ingredients into commercial reality.

Sugar Reduction

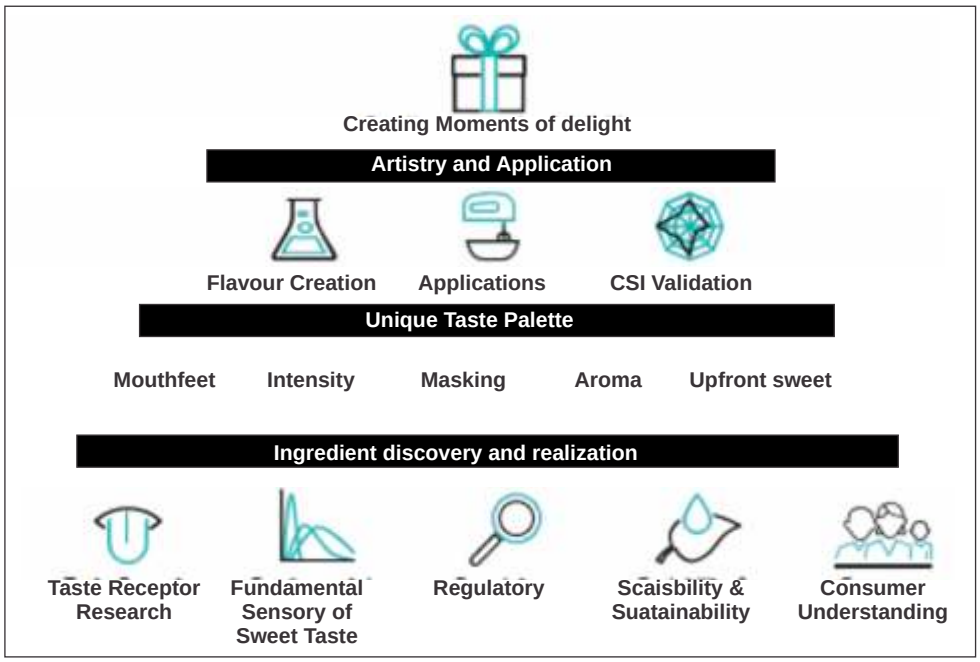
In 1999 a pathway to new discoveries opened. Academics discovered the mechanism – taste receptors on the tongue – for human perception of sweet taste. Prior taste ingredient discovery relied on luck and labor intensive methodologies, but taste receptor research brought scientific rigor and speed to the search for breakthrough ingredients. Industry moved fast, hired experts, built internal process and by 2003 was screening ingredients for taste potential. Over 30,000 compounds have been screened by some companies in the industry.

Understanding sweetness requires groundbreaking sensory work. By dissecting the taste experience, qualities like metallic, liquorice, earthy and bitter emerge, providing insight into the unique profile of sugar versus other sweeteners. This knowledge, embedded in "sweet curves" guides to create measurably more authentic sugar taste in products.

Sugar reduction technologies would involve:

1) *Enhancing sweetness intensity (sometimes referred to as sweetness modifiers, whose goal is to increase the overall perception of sweetness),*
2) *Developing appropriate sweetness quality, or products that improve the profile of High Intensity Sweeteners to be more sugar-like, and*
3) *Providing complete flavor satisfaction (rebalancing and optimizing flavors, as well as complete flavor design targeted at driving holistic drivers of liking, with the goal of allowing for less sweetness intensity while still delivering a fully satisfying taste experience).*

Figure-8: Step by Step Approach for Development of Sugar Substitutes



Source: Presentation on Inovations in Taste Technology for Health Benifits by Ms. Alka Agarwal

Salt Reduction

Flavors are used to recreate the effects of salt in application. Salt is not replaced one for one but instead the role that salt plays in the formulation is assessed and efforts are made to build back the important flavor attributes from the salt into the complete flavor by using the range of captive taste tools for maintaining the desirable salt profile.

Products providing umami flavor can be used as taste enhancers and provide the taste foundation of a flavor. They can be used to reduce the salt content in products and can be used under GMP. Umami is the synergy of complex basic tastes among sweet, sour, salt and bitter. It is the provision of deliciousness, encompassing amino and organic acids. It is subtle and blends well with other tastes to expand and round out flavors. They provide body and depth to a flavor and give a roundness and lingering taste. Apart from MSG many products are being developed to provide umami flavor.

Section Three
Discussion

The following points were made during discussions:

- The use of new technologies will lead to value addition to agriculture and benefit farmers. Discussions on agriculture, food, nutrition and well being should be continued and ILSI-India should organize such activities in different places.
- Computational gastronomy will be the pathway to rejuvenate Indian traditional foods. It will also be beneficial for tourism sector. The 19 ancient scriptures of India like "Charaka Samhita" should be referred for studies on Indian cuisine and to build data base .
- Genome editing can be used to improve the functional, sensory and nutrient properties of cell based meat.
- Scaling up will bring down the cost and price of cell based meat.
- The amino acid profile of plant based meat can be made comparable to cell based meat by addition of missing components / fortification.
- No allergic effect of plant based / cell based meat has been reported.
- Risk assessment and safety procedures should be followed for new products.
- Lifecycle assessment of new products like plant based proteins should be undertaken to study benefits.
- Effect of different non thermal food processing technologies on nutrients cannot be compared. Different technologies can be combined to get the benefits.
- While reducing salt in products both invisible salt (already present in a product like spinach) and added salt should be taken into consideration.

All stakeholders should be informed about new product development and their safety.

Appendix-1

Growth Trends in Agro Food Production

Commodities	Production (mmt)	Processing, %
Agriculture		
Grains – Ce, Pu & Os	285.00	1.00
Horticulture – FV, Sp,	304.00	2.20
Animal Husbandry		
Beef	7.83	21.00
Sheeps & Goats		
Poultry		
Milk	165.00	37.00
Eggs	88.00	--
Aquatic		
Capture	3.90	27
Culture	7.00	

Source: From Keynote Address by Dr. Chindi Vasudevappa

Appendix-2

Agro-Foods - Production, Processing Levels

Commodities	2000 (MMT)	2017(MMT)	Growth* (%)
Agriculture			
Grains – Ce, Pu & Os	199.00	285.00	43
Horticulture – FV, Sp,	127.00	304.00	139
Animal Husbandry			
Beef	5.00	7.83	57
Sheeps & Goats			
Poultry			
Milk	72.00	165.00	129
Eggs	29.00b	88.00b	203
Aquatic			
Capture	5.30	10.90	106
Culture			

Source: From Keynote Address by Dr. Chindi Vasudevappa

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