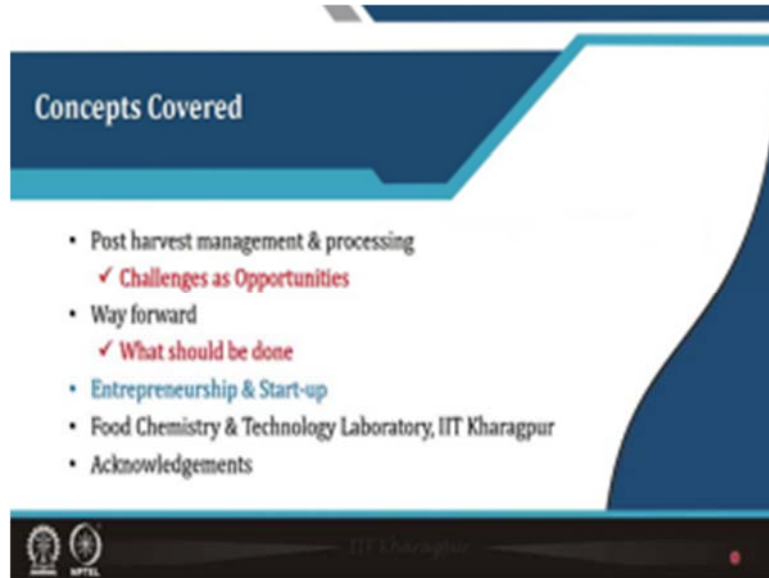
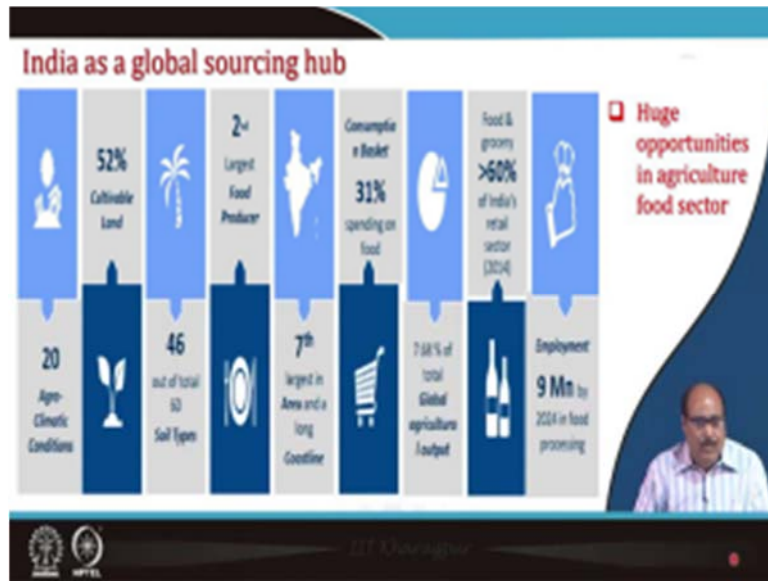


**Post-harvest Operations and Processing of
Fruits, Vegetables, Spices and Plantation Crop Products**
Professor H. N. Mishra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 60
Course Summary and Summing-Up



Hello everyone, we are in the last lecture of the course i.e. summary of the course. We will sum up the course that what we discussed during the entire course. So, let us discuss today about post-harvest management and processing, challenges and opportunities and the way forward.

I will elaborate briefly on Entrepreneurship and start-ups. In the end, we will discuss the R&D activities of my laboratory, the Food Chemistry and Technology Laboratory at IIT Kharagpur.



India as a global sourcing hub

You know that India is a global sourcing hub. There are about 20 agroclimatic zone/conditions, 52 percent cultivable land, and 46 out of total 60 soil types available in India. India is the second largest food producer in the world, and seventh larger in the area and it has a very long coastline. There is about 31 percent of the consumption basket is spent on food, 7.68 percent of the total global agriculture output and more than that, Food and Grocery have more than 60 percent of the Indian retail sector (2014 data). Agriculture and Food Processing Sector, particularly the Food Processing, if everything goes as per the plan, by 2024 it will employ 9 million people.

So, all this data shows that there are huge opportunities in the agriculture and food sector in India.



Agri food ecosystem

Let us discuss the Agri-food ecosystem. Food processing involves right from crop production till it comes to the consumer table. The food has to undergo different stages where various operators are involved like the food producers, primary food producers and manufacturers, secondary manufacturers, wholesalers, retailers, food service operators, caterers etc. The food manufacturing company have to make a proper balance and each and every stage adopt standard practices. Standard operators should take care of the statutory and regulatory body on one hand and consumers' preferences or consumer demands on the other. So, this whole makes the Agri-food ecosystem.



Agriculture food sectors

We can divide the Agriculture and Food Sectors into 5 major categories. One is the durable crop sectors which include grain, cereals, legumes, oil seeds, etc. Second is the perishable sector i.e. fruits, vegetables, dairy products, meat, fish and poultry. The third category may be the commercial crop sector which includes tea, coffee, cocoa, and so on. There is another sector which is considered an unexplored underutilized crop sector like non-timber forest produces and millets. Finally, the health-value crops include spices, condiments and many health-beneficial fruits and vegetables.

So, in this course, we considered mainly the perishable foods i.e. fruits and vegetables, the commercial crops tea, coffee, cocoa etc., and the health-value crops like spices, condiments and other beneficial fruits and vegetables. So, this constitutes a major section of the agriculture and food sector.

Major challenges in various sectors

Fruits & vegetables

- Short shelf life & deterioration of nutritional & sensorial quality
- Lack of modern harvesting practices and cold storage
- Inappropriate post-harvest management

Health-value crop sector

- Lack of technical skills
- Toxicity of residual agrochemicals used for pest management
- Lack of value addition, quality upgradation
- Improper post-harvest practices

Commercial sector

- Climatic hazards
- Prevalence of diseases & pests
- Difficulties in clearing of dense vegetative cover
- Soil erosion due to over exploitation



Major challenges in various sectors

Different sectors have different challenges. Look at these three sectors which we have covered in this course. In fruits and vegetables, the major challenge is how to increase their shelf-life. Because of the shorter shelf-life fruits and vegetables are perishable in nature. There is a fast deterioration of nutritional and sensorial characteristics. The other challenges are the lack of modern harvesting practices and cold storage infrastructure, inappropriate post-harvest management, etc.

If you look at the health value crop sector, there are lack of technical skills, the toxicity of residual agrochemicals used for pest management, a lack of value addition and quality upgradation and improper post-harvest practices. In the commercial crops sector, climatic hazards, prevalence of diseases and pests, difficulties in the clearing of dense vegetable cover and soil erosion due to over-exploitation.



Reducing supply chain losses

In the post-harvest management of fruit and vegetable, reducing the supply chain losses is a major challenge because, in these categories, huge losses of fruits and vegetables occurs, in some cases as high as 35 to 40 per cent losses in perishable have been also reported. In the supply chain, there are 2 stages i.e. the upstream stage like agriculture which involves production, post-harvest handling and storage, and the downstream stage, the processing and packaging, and distribution and consumption are involved.

So, the appropriate plant processing infrastructures in the upstream stage and efficient processing and storage and distribution in the downstream stage are the best strategies to reduce supply chain losses and these are very important in the consumption and utilization of fruits and vegetables concerned.

Post harvest management : Challenges as Opportunities

□ Areas of PHM with new possibilities

- Farm level processing - Venture for minimal processing of F & V.
- Local manufacture of primary processing machineries - Make in India
- Cold chain and preservation infrastructure facilities are to be without any break from the farm gate to the consumer
- Shortening the distribution chain - B2B Ventures
- Value addition of fruits and vegetables - IME, HMFP, etc.
- Byproduct utilization - Extraction of bio-actives, Functional foods

Post-harvest management: Challenges as Opportunities

In post-harvest management, one has to take the challenges as opportunities. Like farm-level processing, promote more and more ventures for minimal processing of fruits and vegetables. Farm-level minimal processing means grading, sorting, packaging, etc. Local manufacture of primary processing machinery i.e. the make-in-India concept is very important for farm-level processing and it should be encouraged. Cold chain and preservation infrastructure facilities are to be established without any break from the farm gate to till it comes to the consumer.

Furthermore, shortening the distribution chain by having more and more B2B Ventures to reduce as far as possible the distribution cycle, distribution chain should be encouraged. The value addition of fruits and vegetables like intermediate moisture, high moisture fruit products, and fermented products can be done. Finally, by-product utilization where extraction of bio-actives, biofuels, functional foods preparation, etc. should be explored.

Way forward - What should be done?

- Utilization of the information/knowledge generated through on-going farm practices to develop novel technologies.
- Application of novel technologies for enhancement of shelf life and adoption of zero waste processing strategies.
- Pilot studies, modelling and upscaling of the developed processes.
- Establishment of technology / product demonstration units.
- Entrepreneurship development & Start-up promotion.
- Knowledge dissemination & awareness creation.

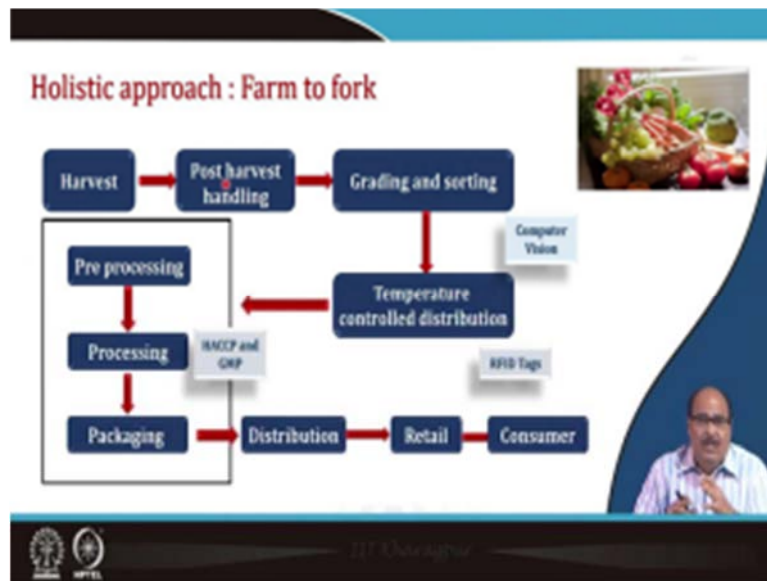
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Way forward – What should be done?

Utilization of the information and knowledge generated through ongoing farm practices to develop novel technologies in the different parts of the country can be studied and this should be used to develop the novel technologies and finally, application of novel technologies for enhancements of shelf life and adoption of zero waste or near zero waste processing strategy can be explored.

Pilot studies of these technologies, modelling and the upscaling of the process should be conducted. Another important strategy should be adopted for the establishment of technology or product demonstration units and facilitation of the technology transfer. Entrepreneurship development and start-up promotion are important activities which should be encouraged.

Knowledge dissemination and awareness creation among farmers, consumers, process, and entrepreneurs will be inferred some means to be used to communicate and in fact, this course had been one such means, where we tried to disseminate the information to various users.



Holistic approach: Farm to fork

There should be a holistic approach from farm to fork i.e. starting from the harvest till it reaches the consumer. In the post-harvest handling, grading and sorting, the temperature-controlled distribution system, and computer vision systems should be used in pre-processing, processing and packaging. The HACCP and good manufacturing practices are to be followed carefully and finally, the distribution in retail and to the consumer. So, at each and every stage proper care should be taken, and every possible effort should be taken to make sure that the product is safe and it is of good quality.

Aspects covered in the course

- Novel and emerging methods & technologies for post-harvest handling, transportation, processing and packaging of major fruits, vegetables, spices and plantation crop products were discussed in the course.
- Minimal processing strategies and such other methods for producing quality RTE & RTS foods & beverages; hurdle technology concept for preparing IMF / HMFP; CA storage, MA packaging, edible coating, etc. for extending shelf life of whole as well as cut fruits and vegetables were taught.
- Use of environment friendly green technologies and approaches for near-zero waste processing and utilization of by-products and wastes streams with a focus on creation of wealth from waste were covered.

Aspects covered in the course

Various aspects are covered in this course, and novel and emerging methods and technologies for post-harvest handling, transportation, processing and packaging of major fruits, vegetables,

spices, and plantation crop products were discussed in the course. Even minimal processing strategies and other methods of producing quality ready-to-eat, ready-to-serve foods and beverages and even hurdle technology concepts for preparing intermediate moisture food, high moisture crude products, dehydrated fruits, juices, paste, and fermented products from fruits and vegetables were taught.

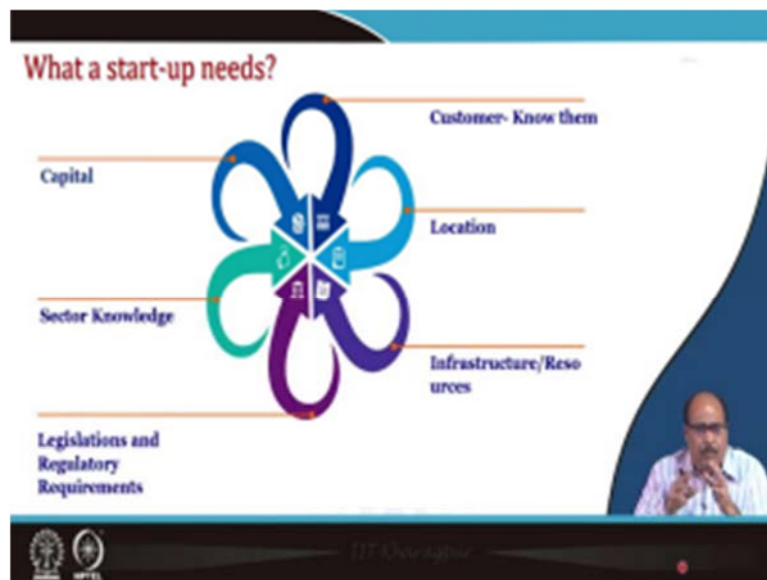
Various methods for extending the shelf life of whole as well as cut fruits and vegetables such as CA storage, modified atmosphere storage, edible coating, etc. were taught in this course. Also, the environment-friendly green technologies and approaches for reducing the carbon footprint in the environment used by the fruits and vegetable processing industries were discussed. The novel approaches for the near-zero waste processing and utilization of byproducts and waste streams into the value-added product and ingredient preparation for the food industry etc. were studied. The focus of the course was on the creation of wealth from waste or byproducts, and their utilization. So, all these aspects have been covered in this 12-week course.



4 Keys to Success

So, I will finally summarize the course by saying that there are 4 keys to success i.e. processing, packaging and shelf life extension, storage and distribution, and marketing and retail. These are essential in any food processing line, but because of the perishable and short shelf-life of fruits, vegetables, plantation, and horticulture crop products, they play a particularly significant role in these industries. At present only a 2 to 3% processing rate only. We have to take every possible effort to increase the processing, convert them into a value-added product, packaging and shelf life of the whole processed product and cut fruits and vegetables.

Proper supply chain management should be adapted for storage and distribution. Finally, equally important, the marketing and retail i.e. the entrepreneurship and the startup promotions should be encouraged as far as possible. So, let me little bit elaborate about entrepreneurship and startup promotion also.



What a start-up needs?

It needs the customer to know how, i.e. who are the customers, what they want, etc. There is a need for some capital and sector knowledge, then the location or some facilities, or place etc. and other infrastructure resources. Finally, control over the information of the regulations, legislations and regulatory requirements etc. So, this is the information which a startup must regenerate before going to the business or a startup processing. They should have a clear understanding of all these things.



Steps in setting up a business

For setting up a business i.e. the step-by-step, requirements include a clear business plan, appropriate or proper funding for doing that business, products, operations, production line, operation staff, machinery, etc. and finally licensing and marketing. These are the various steps in chronological order that are involved in setting up a business.

The business plan

- It is a means of communicating your vision to the outside world to help you attract talent and money to your enterprise.
- The quality of a business plan is measured by its ability to hire employees, gain contracts from potential customers and negotiate monetary investment from an investor who's interest is solely to make profit.

Expectations from a good business plan

- Well thought out and can be visualized
- Clearly outline the risks associated
- Should compel action and get investors excited
- Articulates the strengths and the vision of your business
- Present clear evidence of the viability of the venture

The slide also features a small video inset of a man in a white shirt and glasses speaking, and logos for IIT Madras and IIT KGP at the bottom left.

The business plan

A business plan is a very important document for any startup or any entrepreneurship activity. It means communicating your vision to the outside world to help you attract talent and money to your enterprise. This is a plan a document that tells one who reads this document to understand your vision. The quality of a business plan is measured by its ability to hire employees, gain contracts from potential customers and negotiate money investment from an investor who is interested in solely making a profit.

Expectations from a good business plan: It should be a well-thought-out document and can be easily visualized. This should articulate the strength and the vision of your business; this will clearly outline the risk associated with this business and it will present clear evidence of the validity of the venture. In fact, it should compel the action and get investors excited i.e. the one who reads your business plan should get excited to associate with your business either in any form or to give the funding to join it in a suitable way.

Government schemes

- ✓ The Indian government has introduced over 50+ start-up schemes in past few years.
- ✓ Each start-up scheme is missioned towards boosting the Indian start-up ecosystem.
- ✓ Various start-up schemes are launched by different government agencies targeting different area.

नीति आयोग
National Institution for Transforming India

Government schemes

There are various Government of India schemes, particularly in the past few years, the Government of India has been very proactive to promote start-up and entrepreneurship-developed activities, etc. It has introduced over 50 plus start-up schemes in the past few years. Each start-up scheme is missioned toward boosting the Indian start-up ecosystem. Various schemes are launched by different government agencies like Niti Ayog, NSIC, Sidbi, MSME, NSERB India, Ministry of Food processing industries, AIM or even the department of heavy industries. Various departments in the Ministries of the government in agriculture, the RAFTAAR scheme, and NABARD provide funding also to agriculture and food start-ups and provide seed money and other loans.

List of license required

Food License	For making an food processing plant, FSSAI provide license for doing that. Heavy penalties have to be paid if run without this license.
Trade License	Food business is usually granted Trade License as an 'Eating House' under the Municipal Corporation laws of the respective States in India.
Company registration	Registration of the company should be done at the Register of Companies; under the business SSI at the local DIC office.
GST registration	Can be easily done at the online website.
Establishment registration	Every owner of a shop or commercial establishment, having more than 10 employees, must obtain a shop and establishment registration from the respective State Labor Department.
Fire department NOC	A no-objection certificate (NOC) from the fire department is required to run for the food business. No fee is required for taking the NOC as of now.

List of licence required

So, to start a business or a food business, there are certain requirements like licenses, which

are required. Number one is the FSSAI Food licence which is an important and mandatory requirement. For making a product processing plant, FSSAI provides a licence for doing business that and if one is not taking the licence and doing the food business, heavy penalties may be imposed. So, to get these licenses, one has to visit the FSSAI website etc., wherein all the details are available, then one has to obtain the trader licence i.e. food business is usually granted Trade Licence as an “Eating House” under the Municipal Corporation laws of the respective State in India.

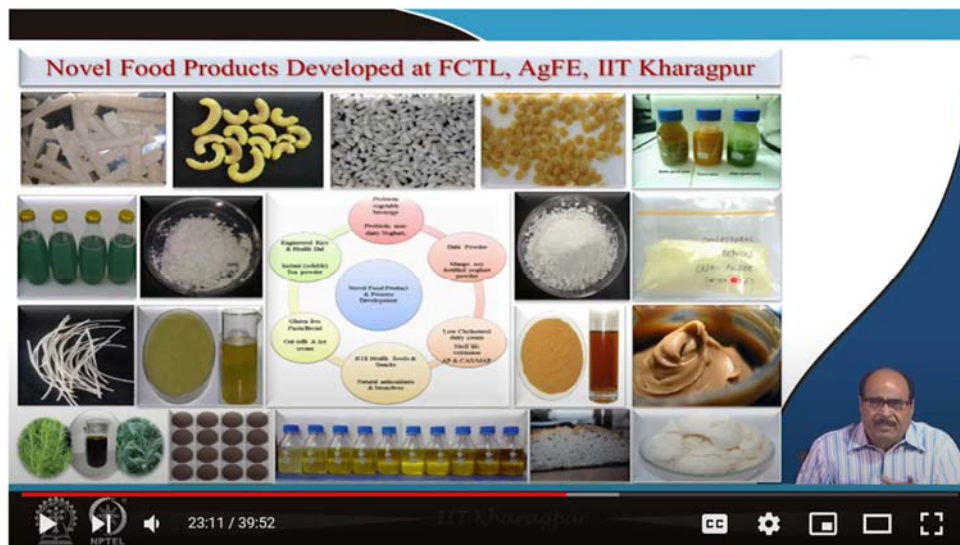
Registration of companies should be done at the Register of Companies or under the business SSI at the local DIC office. GST registration can be easily done on online websites. Every owner of a shop or commercial establishment having more than 10 employees must obtain a shop and establishment registration from their respective State Labour Departments. A no-objection (NOC) from the fire department is required to run the food business. So, NOC from the fire department is required to run the food business and at present, there are no fee requirements for taking the NOC.



Food Chemistry and Technology Laboratory, IIT Kharagpur

Now, let us discuss the Food Chemistry and Technology Laboratory. This is the website logo, you can if you are interested, you can visit our lab website at www.fctliitkgp.co.in. This is a research and development laboratory where we conduct research in the area i.e. new product development, process and machinery development. About 75 percent i.e. three fourth of our activity in the laboratory is focused towards process and machinery development and one-fourth is new product development. If you look at the specific area i.e. sector-wise, we concentrated around about 20-22 percent on the fruits and vegetable technologies and equally about 21 percent are ready-to-eat products i.e. extrusion technology sector. About 30 percent we are

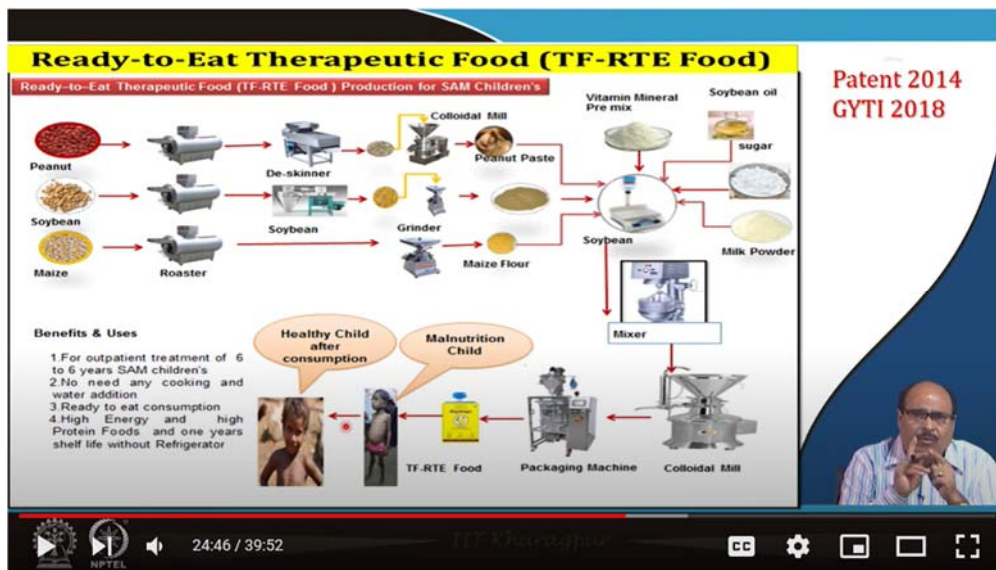
developing functional foods which again include from fruits vegetables, spices etc. Roughly around 14 percent to 15 percent, the dairy foods, as well as the extraction and purification of various bio-actives from ingredients from the various raw, produce materials.



Novel Food Products Developed at FCTL, AgFE, IIT Kharagpur

These are some of the major products which have been developed in our FCTL laboratory at Kharagpur. This includes various ready-to-eat products, algal food biotechnology, tea processing where we filed a patent for black tea, green tea and green tea tablets, antioxidants, oil processing, ready-to-eat health foods, Oat based ice creams, low cholesterol dairy cream, black tea powder, green tea powder, probiotic vegetable juice, extruded traditional ready to eat snack foods and traditional health foods, etc.

Most of these are patented and some of these have also been transferred to various laboratories. So, we will take up at least some of the important processes are indeed developed particularly in the last 5-6 years.



Ready-to-Eat Therapeutic Food (TF-RTE Food)

Let us discuss ready-to-eat therapeutic food for severely acutely malnourished children. This is a patented process and received the GYTI appreciation award in 2018. In this process basically, various locally produced agricultural materials like peanut, soybean, maize etc. are taken and these grains are made to ready-to-eat form by roasting, grinding and de-skinning, converting it into powder form. These grain powders, peanut paste, vitamin and mineral premix, edible oil, sugar, and milk powder in appropriate proportions are mixed. The formulations are developed using linear programming. We have developed 5 formulations from these commodities. Each formulation meets the requirement set by the FAO or WHO for a severely acute malnourished child. This is finally packaged or it is in the form may-be ready-to-eat, ready-to-serve form, or in the party pouches, etc. So, the mother cuts and open these pouches and just feed the child, because, in severely acute malnourished management i.e. normally for children which are up to six months to six-year, there should no need for further preparations. It is hygienic form and is consumed directly and liked by the children. So, this is one product which we have prepared.

Micronutrient fortified rice for mitigation of anemia

Extrusion is the most promising technology for the rice fortification

Micronutrient fortification level for rice

Micronutrient	FRK	MFR
Iron (mg/100g)	280 – 425	2.80 – 4.25
Folic acid (µg/100g)	750 – 1250	7.50 – 12.50
Vitamin B ₁₂ (µg/100g)	7.5 – 12.5	0.075 – 0.125

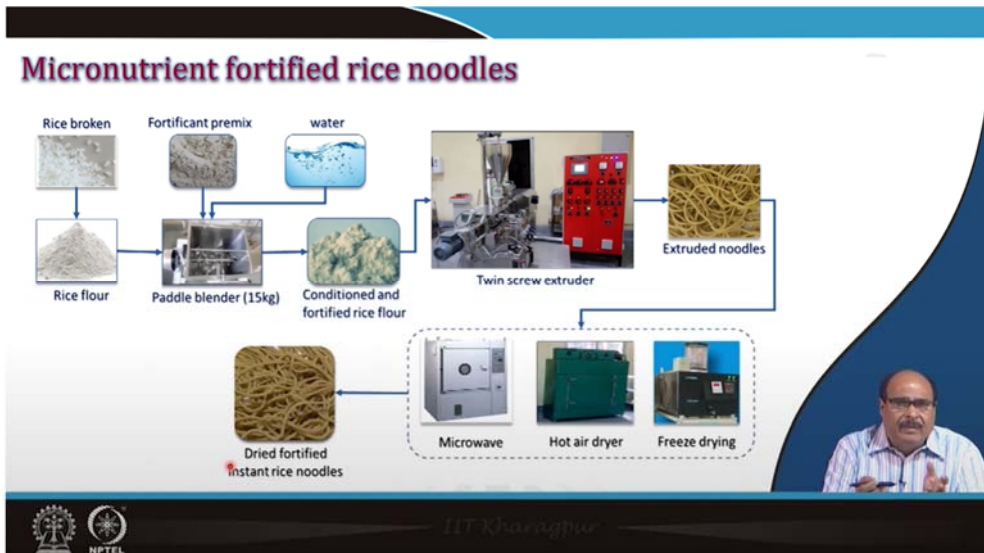
Patent 2016
GYTI Appreciation 2019

Pilot plant capacity
100 kg FRK /day

Micronutrient fortified rice for mitigation of anemia

Another important product that we have done and again it is a patented process, is a micronutrient fortified rice for mitigation of the anemia. Here, we are using the extrusion process because the extrusion is considered to be the most promising technology, where the broken rice is taken, pulverized, and vitamin-mineral premix as per the FSSAI requirements are mixed. Then broken rice flour-vitamin & mineral mix was conditioned. It is fed to the twin screw extruder where which is given the shape of the rice kernel i.e. fortified rice kernel. These fortified rice kernels then are mixed into normal rice for which we have developed a normal rice-FRK mixing unit which gives the fortified rice the required composition.

The fortified rice has a higher level of Iron, folic acid and vitamin B₁₂ and we have also established the pilot scale unit which has a 100 kg FRK production per day capacity in our departmental premises. This is all about fortified rice kernel manufacturing.



Micronutrient fortified rice noodles

The same pilot plant we are using for the manufacture of noodles, just by changing the die in the earlier fortified rice kernel. Now here, the rice die is replaced with a noodle die. In India, anaemic children and ladies are more and they may like to eat noodles than rice. So, the rest process is the same as that of FRK. One more thing also which we have done here that we have also developed a process to replace the fortified premix by using natural ingredients to increase the vitamin and mineral content in the fortified rice noodles.



Low glycemic rice for diabetic persons

The other product is low glycemic rice for diabetic persons. The linear programming technique was used where broken rice, barnyard millet, foxtail millet and quinoa in appropriate proportions were taken for formulation. These grains were milled, sieved, and mixed to get multigrain flour. This multigrain flour is moistened and conditioned to be fed the same extruder where the rice die is used. The dried low-GI rice is good for the diabetic person because the

proper combination of barnyard millet, foxtail millet and quinoa maintain a low glycemic index i.e. more resistant starch content.

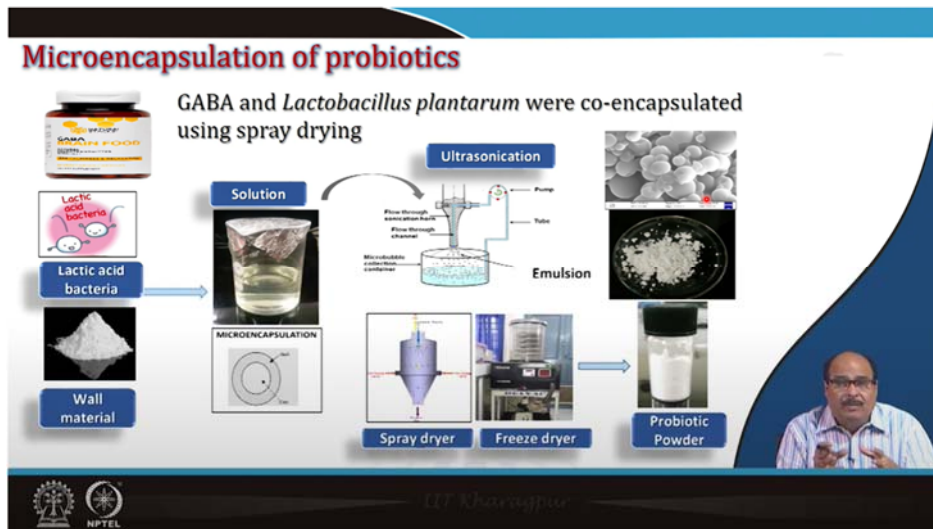
Essential amino acid balanced nutri dal

Another product is the essential amino acid balanced nutri dal. This dal resembles the natural dal, it has a shorter cooking time and less anti-nutritional factor. In an earlier case, the rice broken was taken and here the broken dals, by-products of the dal mill industry were taken in the appropriate quantity and converted into powder, mixed in the appropriate quantity and fed to the extruder to produce the dal. Extruded dal is balanced in essential amino acids i.e. all the essential amino acids meet the requirements as that of the egg. If you take a 100-gram dal and a 100-gram egg, their essential amino acid composition will be comparable or similar.

PUFA Enriched Vegetable Oil Powder

PUFA-enriched vegetable oil powder in which we are balancing the MUFA and PUFA ratio.

The sunflower oil, sesame oil and some other vegetable oil are blended into proper proportion, so as to have a maximum antioxidant value, maximum unsaturation level and also a properly balanced MUFA and PUFA ratio. In this, certain wall materials are used i.e. homogenous emulsion is prepared and this emulsion is finally either spray-dried or microwave dried to get the powder. Oil powder can be used in replacing saturated fat either in bakery products or in the frozen dessert industry. This can give a good healthy alternative to saturated fats.



Microencapsulation of probiotics

Another is the microencapsulation of probiotics. The probiotic bacteria powder contains GABA, gamma-aminobutyric acid which is a neuroprotectant and the *Lactobacillus plantarum*. They were co-encapsulated using spray drying. Here the lactic acid bacteria, GABA and the wall materials are taken into a solution and ultrasonicated to form an emulsion which is spray-dried or freeze-dried to get probiotic bacteria powder. This probiotic bacteria powder has very good stability i.e. more than 2 years, and its bacterial count is maintained even in refrigerated conditions. These probiotic bacteria can be used in various bakery, and confectionery products as well as in beverages.

INSTANT SOLUBLE MILK TABLET

**Patent 2019
GYTI, 2021**

**Overall cost:
Rs. 4 per 10
tablets**

**Students
Army officials
Frequent travelers
Tea or coffee lover**

- Opening and quantification is easy.
- Ease in carrying and storage.
- Low Hygroscopicity of tablets.

**Skim Milk
Tablets**

Conditioning

Compression

Analysis

SMP tablets

Skim milk powder

LOW COST

32:16 / 39:52

Instant Soluble Milk Tablet

The other product is instant soluble milk tablets. Here we have designed the milk tablet-making machine. The skim milk powder is taken, conditioned, compressed and converted into an SMP tablet. SMP tablets can be taken, and whenever required it is convenient to carry. It has good solubility and can be used instead of milk powder for making tea or coffee. This idea is done, now, the next part is antioxidant powders, fruits and vegetable juice powders, which can also be tableted. Tea powder gives antioxidants, so making it in a tablet is one possibility.

Membrane-filtered & Ozonised Shelf Stable Sugarcane Juice

**Patent 2019
GYTI Appreciation 2021**

Crushing → **Microfiltration (Pre-filtration step)** → **Ultrafiltration** → **Ozone treatment** → **Juice with enhanced shelf stability**

Raw juice → **Processed juice** → **Stored product**

Set-up processing of sugarcane juice

Cost of processing: Rs. 30/L

Target population: Sports persons, Jaundice patients

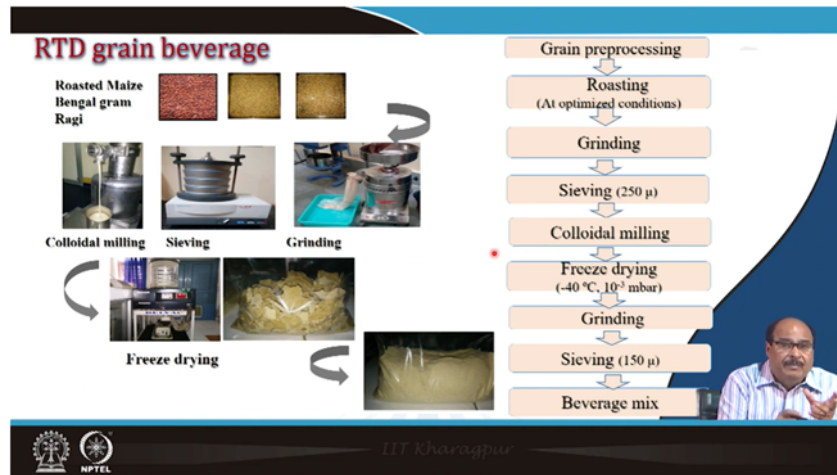
- ~ 6 log reduction in bacterial count.
- ~ 4 log reduction in yeast and mold count.
- ~ 97% reduction in PPO enzyme activity.
- Shelf life of 3 months under refrigeration.

32:50 / 39:52

Membrane filtered & ozonised shelf-stable sugarcane juice

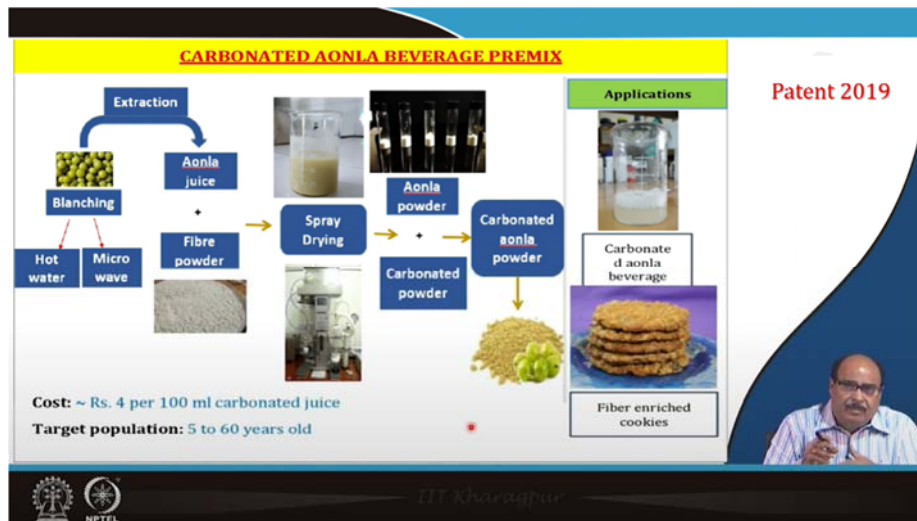
We have Membrane filtered and ozonized shelf-stable sugarcane juice where ultra-filtration and microfiltration processes are used to remove the bacteria and undesirable enzymes present in the juice followed by ozone treatment and packaging. You can see here the raw juice and the processed juice. It had a shelf life of about 3 months under the refrigerated condition. There are

6 log cycle reductions in the bacterial count and 4 log cycle reductions in yeast and mold count. Almost 97 percent reduction in Polyphenol oxidase enzyme activity was observed.



RTD grain beverage

In ready-to-drink grain beverages, roasted maize, Bengal gram, and ragi were taken. They are ground, sieved and passed through colloidal milling to make a slurry and finally freeze-dried. So, in this instantized grain mix powder, the probiotic is added in a calculated amount to get a probiotic grain beverage.



Carbonated Aonla Beverage Premix

There is another carbonated aonla beverage premix it is discussed in carbonated beverages lectures. So many other similar fruits and vegetable products we have discussed in various lectures covered earlier. In this, aonla is blanched in hot water and microwave and aonla juice powder is prepared using a spray dryer. Carbonation powder is also developed.



FCTL Publications

These are some of the publications of our laboratory which include food products and process innovations in different 2 volumes and functional foods. Many other lectures compendium, laboratory manuals etc. are published. These are available in soft copies as well as hard copies.



Acknowledgement

Finally, now I come towards a very important component of today's part which is my duty to extend our acknowledgements and thanks to all those who contributed to this wonderful lecture in this course i.e. in preparation for the course.

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- Contributions of Teaching Assistants & Ph D research scholars of the FCTL are thankfully acknowledged.
- Special thanks are due to
Ms. Monalisha Pattnaik
Mrs. Jayshree Majumdar
Mrs. Anjali Thakur
Ms. Nithya Michael
Mr. Sourav Misra
Mr. Anas Sheikh

IIT Kharagpur

Teaching Assistants

So, first of all, I thankfully acknowledge the role of the teaching assistants. Dr Chandrakant Genu Dalbhagat is the project officer. He did PhD in Food Process Engineering, M Tech in Dairy and Food Engineering from IIT Kharagpur both under my supervision and B Tech in Agricultural Engineering from MPKV Rahuri. Another teaching assistants are Shubham Mandliya who is a Prime Minister Research Fellow, presently doing PhD under my supervision. He did M Tech from IIT Kharagpur with me, and B Tech from JNKVV, Jabalpur. Mr Sidharth Vishwakarma under teaching assistant, is a research scholar, GYTI Awardee, working on a PhD degree with me. He did also M Tech under my supervision at IIT Kharagpur and B Tech from JNKVV Jabalpur.

So, the contributions as I told you of these teaching assistants, and there are other PhD research scholars of the Food Chemistry and Technology Laboratory who contributed immensely to this course. Everybody's effort and contribution are thankfully acknowledged and a special mention that it deserves to Miss Monalisha Pattnail, Misses Jayshree Majumdar, Miss Anjali Thakur, Miss Nithya Michael, Mr Sourav Misra and Mr Anas Sheikh. These are research scholars who are working with me for their PhD degrees and deserve special mention. They also contributed immensely to the preparation of various lecture materials. So, the contribution of teaching assistants and other PhD scholars is thankfully acknowledged.

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IIT Kharagpur

Video and lecture recording team

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NPTEL

Finally, the NPTEL, there are many other people who are involved in various operations in the

NPTEL here at our institute IIT Kharagpur as well as in the national NPTEL-Swayam implementing Institute IIT Chennai. So, the IIT Chennai NPTEL team, IIT Kharagpur NPTEL team and then finally IIT Kharagpur as an Institution and the Ministry of Human Resource Development, Government of India who develop this unique portal and who are encouraging and contributing immensely to the knowledge generation and knowledge upgradation in the country.

And Finally, I like to thank my department, the Agricultural and Food Engineering Department for providing me with this opportunity and permitting me to give this course or to put it in the public domain. I have tried my level best and my team has tried its best to put as much as information possible in the public domain with this course. I hope you all will enjoy this. Finally, wishing the participants of this course, all the best in their future endeavours. Thank you and Jai Hind.