REPORT ON TRAINING PROGRAMME

“EMERGING TRENDS IN FOOD PROCESSING TECHNOLOGY – PROSPECTS & OPPORTUNITIES”

14-09-2005 to 4-10-2005

PREFACE

India has an edge to compete in global market in food processing sector owing to its varied climate and vast reservoir of man power. Currently India has surplus production of agricultural commodities, dairy and marine products. The need of the hour is to concentrate our efforts on improved processing techniques in view of the consumer's quest for products that can provide variety as well as health benefits. Tailoring the technology to fulfill the needs of the consumer would not only provide an impetus to research potential of scientific community, but also enable the industry to benefit from tried and tested technologies for adoption. Growth in food processing industry invariably improves rural economy and standard of living of rural population and at the same time prevent migration of rural population to urban areas, moreover, the diversity of processed Indian foods have the ability to cater to the rich and the poor, national and international consumers alike. India has already made a headway into the global market in processed foods. In order to become a major exporter and make its presence felt in international arena, the country would require a sustained policy programme, support from central and state governments, infrastructure development and human resources development in the area of food processing.

Food processing and technology development is a thrust area of work in SAUs and the developed technologies could be gainfully transferred to industry and help sustain the linkage and benefit the society as a whole.

In view of the identified needs, the programme has been planned with the objectives to explore viable, need-based existing food technologies available, to assess the prospects and challenges of available technologies for industrial application, to help food scientists channelize research and development efforts in required direction and to develop and strengthen linkages of institutions with industry.

This manual entitled "Emerging Trends in Food Processing Technology – Prospects and Opportunities" includes lectures given under six different categories and covers various aspects on Food Processing Technology which would be of interest to Food Scientists, Nutritionists and Food Processors.

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FOOD PROCESSING – THEN AND NOW

CHALLENGES FOR THE INDIAN FOOD INDUSTRY IN THE NEW MILLENNIUM

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India has a significant competitive strength in food processing, being blessed with unsurpassed natural advantages. The country's varied climate allows cultivation of practically every plant species grown in other parts of the world – ranging from snow-clad mountain slope orchard crops like apples to hot coastal tropical mangoes. Finally, we have a great reservoir of man power – skilled, unskilled, technical, scientific and managerial.

Out country is already the world's largest producer of milk, the second largest producer of fruits and vegetables, has a one-fourth share of the world spices production, is a leading producer of tea, cotton and sugar and account's for half of the world's livestock population. India is in total, the third largest producer of food crops in the world after China and USA. It has a vast coast line of over 7000 km and hence has the potential to develop marine products. We are not only self sufficient but have surplus in many commodities. The paradigm shift that has taken place in Indian agriculture, a shift of focus from mere self-sufficiency to prosperity, a shift of focus from `meeting minimum needs' to `realizing the maximum potential' is the result of synergy of three major policy developments – the economic liberalization initiated in 1991, globalization through engagement with the WTO, and the technological revolution in IT, BT and telecommunication. This synergy has transformed the way trade and business is carried out in India. Today, India is a major player in export of basmati rice, species and marine products, export of fresh fruits and vegetables, buffalo meat oilseed meals, flowers etc. However, the share of our exports is less than 1 % of the International food trade. In terms of value, it is around US $ 6 million against the world total of US $ 700 billion. Compared to this, Brazil's and China's share is 3 % each. There is thus a great potential to increase our food products exports from India. We have the basic resources of raw materials but proper infrastructure needs to be developed.

Though India is in the forefront with regard to production of basic raw foods, the level of processing for perishable products in the country is significantly lower than in other counties like Phillipines, Singapore, Brazil, China and USA. India has an incredibly enormous potential to be a major supplier of processed food products for all the classified regional zones of the world. The diversity of Indian processed food products is such that it can meet the aspirations and demands of most of the countries. The processed food products are able to provide multifold addition to the value of the raw produce. The diversified Indian recipes and cuisine have the possibility to cater to the richest as well as the poorest, meeting their sensory and nutritional demands respectively. All these factors if put together and provided with the desired infrastructure and the necessary material and moral support, would make India as one of the largest suppliers of processed food products in the world.

There is ample scope particularly in the category of traditional and ethnic Indian foods, and considerable head way has been made in this area as is evident by the number of products such as savoury items like bhujia, namkeens, ready-to-eat curries, biryanis etc. in retort pouches, rasagollas etc. which are produced and marketed not only within India but to other counties particularly to USA, UK, middle East and European countries.

The processing of grapes into wine has already attracted an investment of Rs. 100 crores in the State of Maharashtra and this has boosted the performance on product exports. It is envisaged that India can be a major exporter to the world in the years to come. For this to happen, besides strong backward linkage, technological and quality upgrdation and improving scale of production and innovation will be needed. The Ministry of Food Processing Industries is giving a lot of encouragement for the development of this sector. Several Food Parks with common processing facilities have been and are also being established in different states to attract cluster of industries. The food processing sector needs to give modern technological dimensions to the processing of agro-products for value addition so as to eater to the global market. Another aspect of growing concern across the world is that of food safety. The capacity of India to penetrate and capture world market for processed foods depends on its ability to meet increasingly stringent food safety standards imposed in developed countries. Food standards are expected to acquire greater importance given increasing concerns on food safety on the back of breakout of diseases such as BSE. Avian influenza etc. on the one hand and growing consumer demand for products which are healthy on the other. Compliance with international food standards is a prerequisite to gain a higher share of world trade. Quality and safety have to be built into food products throughout the production, processing and distribution chain and this is the basic responsibility of all the stake holders namely, the growers, the processors and the distributors of food.

In summary, India has a miniscule share in a highly competitive export market for processed foods. To make its presence felt in the world market in this share, the country would require a sustained policy programme, a genuine patronage from central and state governments, the technological inputs and upgradation both in terms of process know-how as well as advanced processing machinery. It is necessary for us to take stock of our potential, our strengths, our weaknesses and the challenges we face. The solutions call for bold new initiatives and food processing is the solution to many problems of the Indian agricultural economy and the importance of food processing to the economy of the country can not be over emphasizd. Armed with the ability to meet the challenges, the Indian food processing industry can become the food factory to the world in future.

POTENTIAL FOR FOOD PROCESSING IN INDIA

Topic given during the short course on EMERGING TRENDS IN FOOD PROCESSING TECHNOLOGY PROPECTS AND OPPORTUNITIES

Date: 15-9-2005 Time: 2.00 to 3.30 PM

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India is a strategic player in the world in the food sector

- Is the second largest producer of fruits and vegetables next to China
- Fruits 45.5 million tonnes annually from a area of 3.8 million ha.
- Vegetable 88.62 million tonne from on area of 6.18 million ha.
- Second largest producer of wheat
- Third laregest in food grains (210 million tonnes)
- Largest exporter of cashewnut in the world (Amounts 43% of world production)
- Fifth largest producer of eggs
- Largest producer of milk (91 million tonnes)

Processing of fruits and vegetables

- Only 2 to 3% India (1,206 crores in 2003 to 2,050 crores end of the tenth plan)
- 83% in Malaysia
- 72% in Thailand
- 70% in Brazil

Export

- Meat & poultry – 2%
- Milk by way of modern dairies at 14%
- Fish – 4% (5,957 crores in 2003 – 8,350 crores by the end of the 10th plan)
- Bulk meat de-boning – 21%
  - Philippine – 45%
  - China 23%
  - India – 7%

Cereal based consumer Food Industry

(268 crores)

- Pasta
- Breads
- Cakes
- Pastries
- Rusk's
- Buns
- Rollys
- Noodles
- rice flakes
- Corn flakes
- Biscuits
- Ready to eat and ready to cook product

Note: The bread and biscuits – constituents largest sector (40% in organized and 60% in unorganized sector)

Ministry of Food Processing Industry provide financial support.

12 no. of proposals of cereal based consumer food Industries approved for April 2003 – March 2004.

Osmotic dehydration in fruit and vegetable processing

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Post Harvest Technology of Horticultural crops

Advances in different dehydration techniques have enabled the production of a wide range of dehydrated products and convenience foods from horticultural products, meeting the quality, stability and functional requirements couples with economy. One of the recently developed novel drying method is osmotic dehydration.

Osmotic dehydration (OD) has been considered as one of the preservation methods for perishable food since 1960s . Fruits in general contain more than 75% water and get spoiled very quickly, if not stored properly. Even proper storage fails to preserve the fruits for a long period unless they are dehydrated. It has been widely applied for partial removal of water from food materials. The osmotic dehydration process utilizes the **principle** of water diffusion from dilute solutions to concentrated solutions through a semi-permeable membrane until concentration equilibrium is attained. The semi permeable membrane is more selective for water and acid than solute. The driving force here is the water activity gradient caused due to osmotic pressure. This process mainly deals with removal of water from food and impregnation of food materials with osmotic agents, such as salt, glucose, maize syrup, glycerol, dextrose, sucrose and so on.

For osmotic treatment, the food material (plant or animal tissue) is introduced into an aqueous solution of increased osmotic pressure, i.e. with a relatively high concentration of dissolved substances. OD is a two stage dehydration process. The first stage consists of immersing fruits in a concentrated osmotic solution or in a dry osmotic material, where water is lost, increasing the solid concentration of the produce. However, complete removal of water is not possible resulting in Intermediate Moisture Foods (IMF). The process can be carried out preferably during night time to synchronize with solar or other type of drying in the day time.

Mass transfer

During osmotic dehydration, the difference in concentration of dissolved substances in the cell fluid within the tissue and the osmotic solution, two countercurrent mass transfers can take place: (1) diffusion of water out of the cells (tissue) into the solution, due to osmosis and (2) uptake of solute by cellular tissues from the osmotic solution. The uptake of solute is because of water removal. Therefore, the cells shrink and the intercellular spaces become larger and are filled with osmotic solution. A third mass transfer, leaching out of natural solutes within the food may also take place that can affect organoleptic and nutritional properties of food products. But this third transfer can be negligible compared with the two main countercurrent mass transfer mechanisms.

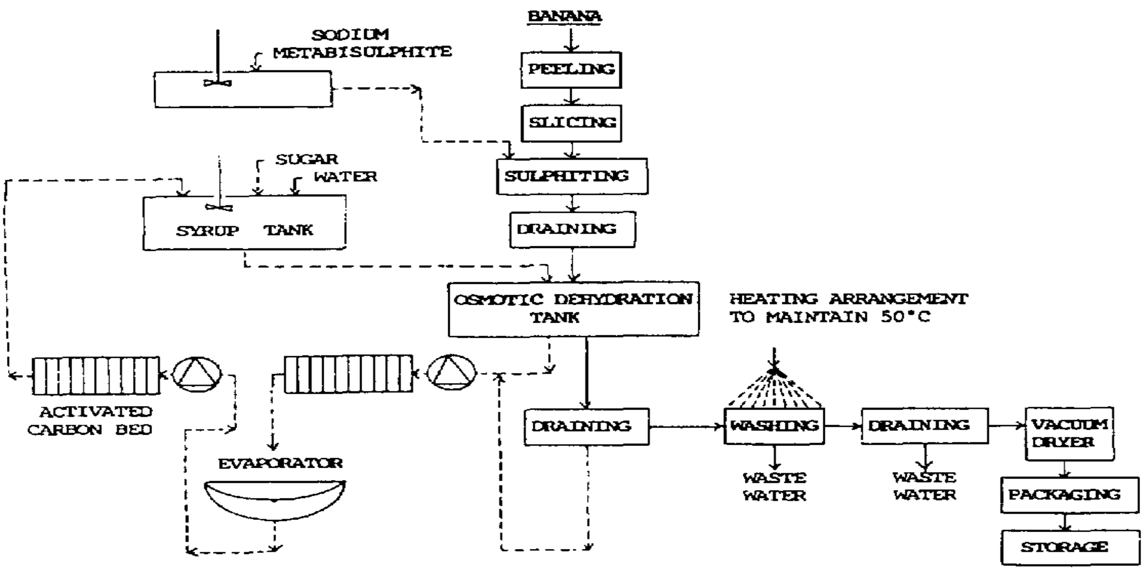
Advantages

It offers the following advantages: (1) prevention of loss of flavor compounds, (2) prevention of cell damage that can be caused by excessive heat, (3) high retention in color and nutritional characteristics of raw material and (4) lower initial investment and operational cost compared to other single drying processes such as vacuum drying or freeze drying (%) decrease in polyphenoloxidase activity and (6) less energy consumption (especially in osmo-solar dehydration) (7) Apart from this, problems of marketing, handling and transport becomes much simpler and all types of fruits could be made available to the consumer throughout the year. Osmotic dehydration can remove 50% of the water from fresh ripe fruits e.g. bananas, mangoes, sapotas, papayas, apples and other tropical fruits, potatoes and sweet potato. The final drying of these osmotic dehydrated fruits by vacuum drying provides a product which has good quality, attributes with respect to appearance, taste, flavor and colour as compared to sun drying. The product is suitable as a ready to eat snack item. Also the dehydrated product could be powdered if desired, and mixed with milk powder for making other products and confectionery items. To alleviate reduction in acidity of fruits, fruit acids are recommended. Quick rinsing of fruits in water can wash away the sugar coating. For economics of the process use of spent syrup is crucial. After 5-6 cycles this syrup has high organoleptic and nutritive value and can therefore be recommended for direct consumption as a commercial product. As it contains about 40% sucrose and small amounts of extracted organic compounds like organic acids, esters, vitamins and minerals, it can be used as a raw material for some biotechnology process.

The Process

The process of dehydration consists of three steps i) Osmotic dehydration, ii) Vacuum or air drying, iii) Packaging. In osmotic dehydration, the fruits are subjected to osmosis by dipping or spreading them in a aqueous sugar syrup under specific conditions, so that the water from the fruits migrates to sugar syrup. Major dehydration of the fruit takes place in this process step. The final drying of the fruits to make it suitable for marketing is carried out by vacuum or air drying depending on the cost considerations.

Flow diagram for osmotic dehydration of banana



Osmotic dehydration is therefore a useful technique for the concentration of fruit and vegetables, realised by placing the solid food, whole or in pieces, in sugars or salts aqueous solutions of high osmotic pressure. It gives rise to at least two major simultaneous counter-current flows: a significant water flow out of the food into the solution and a transfer of solute from the solution into the food.

The osmotic syrup after contact with fresh fruits or other food material becomes dilute and needs re constitution. To this 'spent syrup' sugar can be added or it can be solar concentrated or a combination of solar assisted vaccum evaporation can also be done. The number of cycles this syrup is concentrated should be limited to 5-6 cycles or it leads to darkening of the syrup

Technical data on some osmotically dehydrated products

Fruits	**Type of cut**	**Treatment**
Banana	5 mm slices	2 hours, 80% sugar, 2000 ppm SO_2 at 70°C
Carrots	10 x 10 x 2 mm dices or 5 mm slices	4 hours, 60% sugar + 10% salt, 4000 ppm SO_2
Mango, green	8 mm slices	2 hours, 25% salt, 8000 ppm SO_2
Mango, ripe	8 mm slices	2 hours, 60% sugar, 8000 ppm SO_2
Onions	2 mm slices	2 hours, 60% sugar + 10% salt, 4000 ppm SO_2
Papaya	8 x 8 mm slices	4 hours, 80% sugar, 2000 ppm SO_2 at 70°C
Strawberries	Whole	4 hours, 80% sugar, 4000 ppm SO_2
Sweet pepper red	6mm dices	2 hours, 60% sugar + 10% salt, 4000 ppm SO_2

Parameters influencing the osmotic kinetics and OD process

Water loss and solid gain are mainly controlled by the raw material characteristics and are certainly influenced by the possible pre-treatments.

I. Product parameters

1. Properties of the commodity: variety, maturity, physical structure (porosity, arrangement of cells, fiber orientation and skin) and the chemical composition (protein, fat, carbohydrates, salt etc.)

2. Size ans shape of the commodity: As mass transfer rate is proportional to the exchange surface, a high surface to volume ratio is recommended. Small size fruits should be dehydrated whole.

II. Process variables

1. Pre-treatment : blanching, lye treatment have shown to increase TSS and decrease acidity in fruits. Addition of SO2 or sodium metabisulphite to dipping solution retards browning. Factors which modify the tissue permeability, such as over-ripeness, pre-treatments with chemicals (SO2), blanching or freezing, favour the solid gain compared to water loss as impregnation phenomena are enhanced

2. Composition of osmotic solution: Common salt is best for vegetables and sugar for fruits. Any osmotic agent used should be effective, convenient, non toxic, good taste and readily dissolvable in the solvent .in high concentration, not react with the product and be economic. The kind of sugars utilized as osmotic substances strongly affects the kinetics of water removal, the solid gain and the equilibrium water content. Low molar mass saccharides (glucose, fructose, sorbitol, etc.) favour the sugar uptake; addition of NaCl to osmotic solutions increases the driving force for drying. Synergistic effects between sugar and salt have also been observed.

3. Fruit to solution ratio: The fruit solution ratio of 1:4 to 1:5 has been found to be optimum

4. Concentration of the osmotic solution: Equilibrium and drying rate increase with increase in the osmotic syrup concentration. Dehydration effects increase linearly with increase in sucrose concentration up to 60%. At higher concentration sucrose gain by the fruit was high and this was not desirable. Solute concentrations below 40% caused impregnation in the solid. Therefore 40-60% was considered ideal. There is a concentration maximum, beyond which water loss cannot be improved by increasing concentration.

5. Temperature of osmotic treatment: The reported temperature limit is 50^{o}C as above 45°C enzymatic browning and flavour deterioration begin to take place. Water loss and solid gain increase linearly with increase in temperature. Solid concentration is nearly constant at 60^{o}C. Further increase affects the semi permeability of the cell wall, reducing the rate of osmosis.

6. Agitation / circulation: Osmotic dehydration is faster with agitation. As viscosity of the solution is important for optimum mass transfer on the solution side, agitation decreases the resistance to mass transfer.

7. Time duration: Water loss mainly occurs during the first 2 hr and the maximum solid gain within 30 min and decreases thereafter. Increase of the contact period at constant concentration results in increased weight loss. Time can be fixed in a way to ensure maximum water removal without appreciable intake of solids.

Synergies with other processes

Drying

Air drying following osmotic dipping is commonly used in tropical countries for the production of so-called "semi-candied" dried fruits. The sugar uptake, owing to the protective action of the saccharides, limits or avoids the use of SO_2 and increases the stability of pigments during processing and subsequent storage period. The organoleptic qualities of the end product could also be improved as some of the acids are removed from the fruit during the osmotic bath, a blander and sweeter product than ordinary dried fruits is obtained. Owing to weight and volume reduction, loading of the dryer can be increased 2-3 times. The combination of osmosis with solar drying has been put forward, mainly for tropical fruit. A 24 hour cycle has been suggested combining osmo-dehydration, performed during the night, with solar drying during the day. Two-three-fold increase in the throughput of typical solar dryers is feasible, while enhancing the nutritional and organoleptic quality of the fruits.

A two-step drying process, OSMOVAC, for producing low moisture fruit products was described. The osmotic step is performed with sucrose syrup 65-75 Brix until the weight reduction reaches 30-50%. By osmotic dehydration followed by vacuum drying puffy products with a crisp, honeycomb-like texture can be obtained at a cost comparatively lower than freeze-drying. Commercial feasibility of the process on bananas has been studied and osmotically dried bananas have retained more puffiness and a crisper texture than simple vacuum dried ones with long lasting flavour,

Appertisation

A combination of osmotic dehydration with appertisation has been proposed to improve canned fruit preserves. The feasibility of a process, called osmo-appertisation, to obtain high quality fruit in syrup, has been assessed on a pilot scale.

The key point of this technique is the pre-concentration of the fruit to about 20-40 Brix, that causes, together with the enhancement of the natural flavour, an increase of the resistance of the fruit to the following heat treatment, especially for colour and texture stability. The products obtained are stable up to

12 months at ambient temperature and show a higher organoleptic quality than canned preserved alternatives. Furthermore, because of their higher specific weight and diminished volume, the filling capacity of jars or pouches is increased.

In order to obtain an alternative to the canned fruit preserves and to maintain a high quality of the fruits, a research has been carried out on the osmoappertisation of apricots, a "combined" technique that consists in the appertisation of the osmodehydrated apricots. This technique could contributes also to the reduction of energy consumption, limits the cost of production and combines "convenience" (ready-to-eat, medium shelf-life) with many market outlets (retail, catering, bakery, confectionery, semi-finished products). Osmoappertisation combines two unit operations: dehydration by osmosis and appertisation (packaging + pasteurization).

Freezing

The frozen fruit and vegetable industry uses much energy in order to freeze the large quantity of water present in fresh products. A reduction in moisture content of the material reduces refrigeration load during freezing.

Other advantages of partially concentrating fruits and vegetables prior to freezing include savings in packaging and distribution costs and achieving higher product quality because of the marked reduction of structural collapse and dripping during thawing.

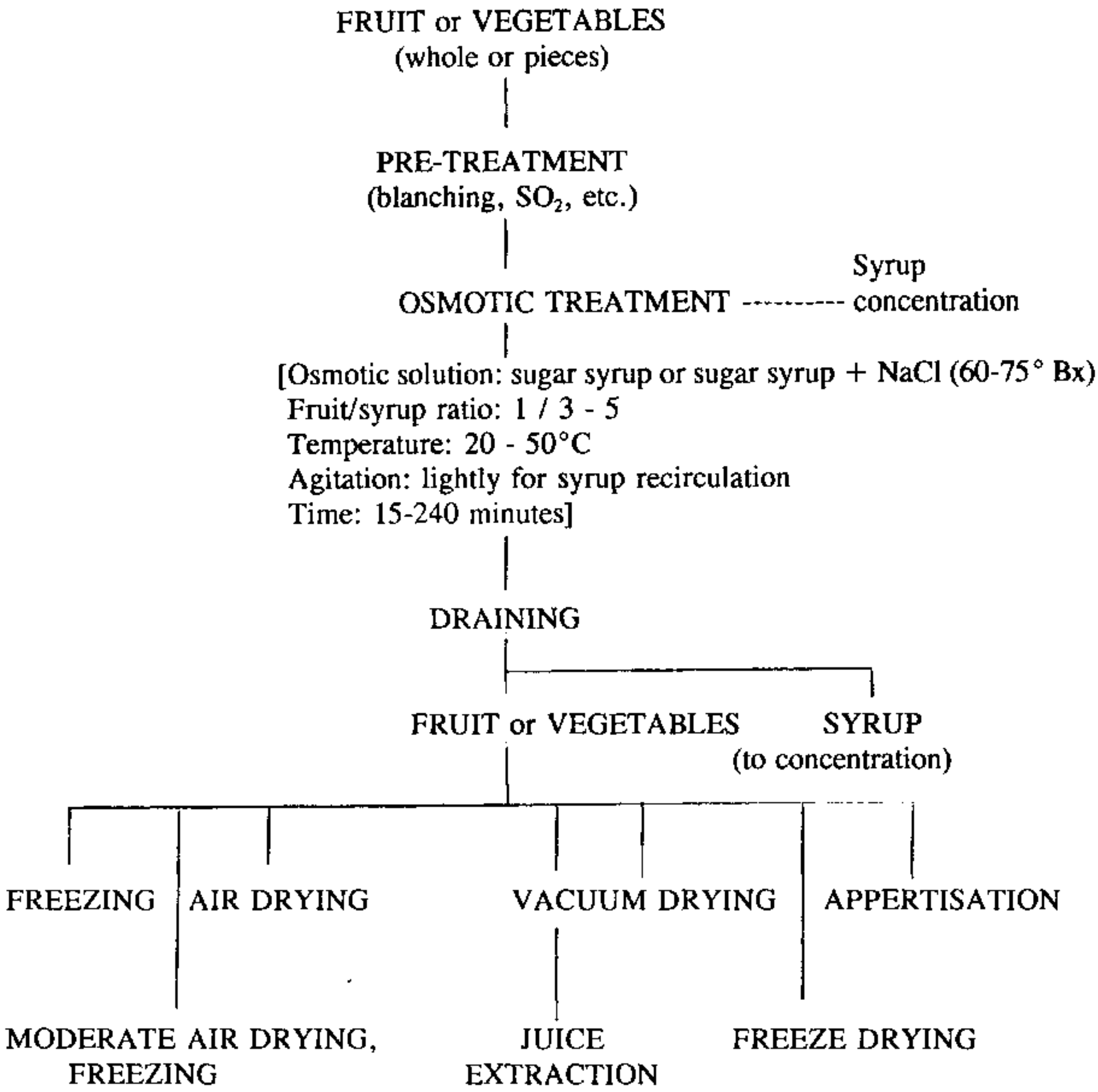
The products obtained are termed "dehydro-frozen" and the concentration step is generally carried out through conventional air drying, the additional cost of which has to be taken into account.

Osmotic dehydration could be used instead of air drying to obtain an **energy saving** or a quality improvement especially for fruit and vegetable sensitive to air drying.

Extraction of juices

An osmotic pre-step before juice extraction was reported to give highly aromatic fruit or vegetable juice concentrates.

Flow diagram of osmo-appertization of fruits and vegetables



Further developments needed

So far only applications on a pilot plant scale are reported in the literature. For further developments on a larger scale, theoretical and practical problems should be solved.

The industrial application of the process faces engineering problems related to the movement of great volumes of concentrated sugar solutions and to equipment for continuous operations. The use of highly concentrated sugar solutions creates two major problems.

The syrup's viscosity is so great that agitation is necessary in order to decrease the resistance to the mass transfer on the solution side.

The difference in density between the solution (about 1.3 kg/litre) and fruit and vegetables (about 0.8 kg/litre), makes the product float.

Another important aspect, so far not investigated, is the microbiological safety of the process, which should be studied thoroughly before further industrial development.

Development in the combined treatment of coating and osmotic dehydration of food

Among the perishable food, fresh-cut fruits and vegetables have several limitations like (1) microbial contamination, (2) discoloration due to enzymatic browning(3) changes in texture, and (4) off-flavor and off-odor. By applying edible coatings, the coated-food provides the following benefits: (1) reduction of respiration, (2) inhibition of water loss and color changes, and (3) improvement in texture and mechanical integrity

The major limitation of osmotic dehydration is the penetration of large amount of solute into the food material. This penetration of osmotic agent into the food brings about the resistance for mass exchange of water in further dehydration processes such as convective drying and freeze drying. A limited solute uptake can also facilitate aroma retention in further dehydration. To overcome this problem of large solute intake, application of coating on food materials such as fruits can be introduced prior to osmotic dehydration. The concept of applying edible coating has been employed for long time to extend the shelf-life of perishable food. Alginates, fats, vegetable gums, proteins and carbohydrates have been applied on fruits and vegetables to prevent physiological and microbial damage and to control gas exchange between the food and surroundings. During osmotic dehydration, coating can act as an artificial barrier to hinder the penetration of solute into the food without affecting greatly on water removal.

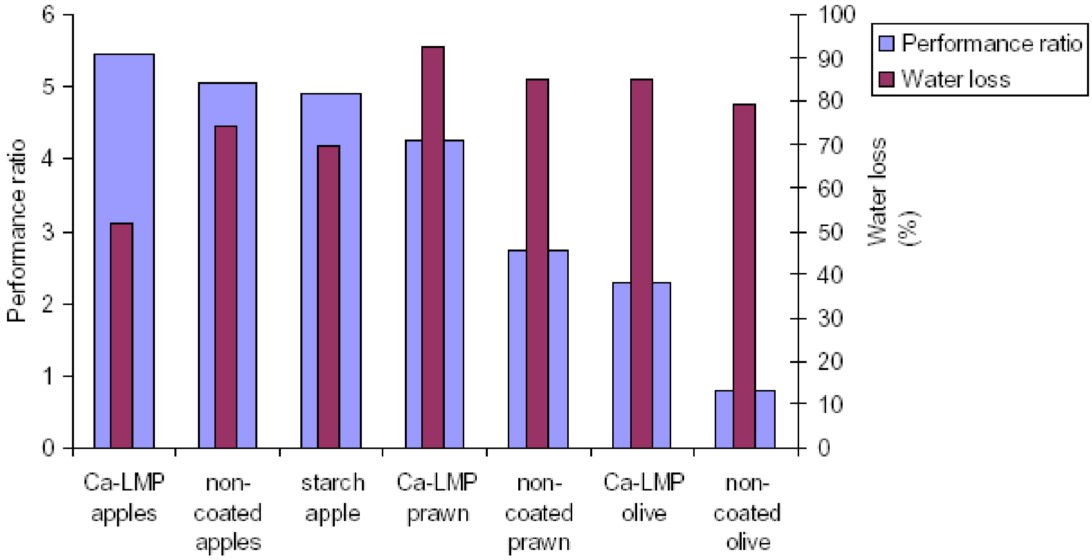


Fig. 1. Osmotic dehydration of coated and non-coated food (Data from Camirand et al., 1968 and Lewicki et al., 1984)

Experimental results have shown that coating on apples could be a solution for preventing the solid gain during osmotic dehydration. The main contribution of coating was to prevent the solute gain; but it can also affect the water removal process reducing the water release from food. Nowadays, it draws increasing attention in food processing industry because it helps to successfully solve some of the quality deterioration problems faced with processing, storage and transportation. Coating could also prevent water loss from oranges and lemons as wax has high hydrophobicity. Edible coating materials could prevent not only water loss but also absorption of oxygen by fruits and vegetables.

Some of the edible polymers used are pure food grade corn starch, sodium alginate, ethyl cellulose, sodium polypectinate, low methoxyle pectin, malto-dextrin, methyl cellulose and potato starch.

Conclusion

This process ahs received attention as it improves product quality with minimum of energy input. This technology also indicates a 4-5 fold increase in the throughput of some dryers. Simplicity of the process, economics involved and unavailability of other chain of other processing methods makes this process attractive for small agro-industries of developing countries to preserve surplus produce at the production site.

PROCESSING OF UNCONVENTIONAL FOODS

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Different species of edible wild foods exist in the natural reserve of forests in the densely populated eastern ghats of Andhra Pradesh. The wild foods have been identified by the indigenous people for their own use, with either cultural, religious or medicinal uses. These traditions mean that such wild foods are highly regarded by the local people.

Increasing development has resulted in a neglect of the values of wild foods in part because there was little education about the importance of local plant resources and their uses. As a result processing of wild foods had declined. There is a need to revive the importance and use of the traditional forest foods in the community. This calls for finding ways and means of processing the foods to add value income generation and employment for their sustenance. Processing of some unconventional foods is discussed here.

Bael fruit is one of the most nutritious fruit, rich in vitamins and minerals. Bael is an indigenous fruit tree of India. The history of this tree has been traced to Vedic period 2000 BC – 800 BC. The mention of bael fruit has been made in Yajurveda. The tree has great mythological significance and it abounds in the vicinity of temples.

Medicinal aspects of Bael

- Marmelosin derived from the pulp is given as a laxative and diuretic. In large doses it lowers the rate of respiration, depresses heart action and causes sleepiness.
- The unripe bael is most prized as a means of halting diarrhoea and dysentry.
- A bitter, light-yellow oil extracted from the seeds is given in 1.5 g doses as a purgative. It contains 15.6 % palmitic acid, 8.3 % stearic acid, 28.7 % linoleic and 7.6 % linolenic acid.
- The bitter pungent leaf juice, mixed with honey is given to cure cataract and fever. With black pepper added, it is taken to relieve jaundice and constipation accompanied by edema.

The bigger size fruits have better quality attributes compared to smaller ones such as high pulp, thin peel, less seeds, high sugar, low phenolics, less mucilage etc.

Chemical characteristics of bael fruit pulp

Moisture – 60.7 %
Acidity – 0.46 %
Total sugars – 8.36 %
Non-reducing sugars : 2.04 %
Tannins – 0.21 %
Pectin content – 2.52 %

Physical characters of the bael fruit

Particulars	**Observations**
Size	Medium
Shape	Spherical, flattered and slightly lobed
Colour	
External	Smooth surface, yellowish green
Internal	Various shades of yellow and orange
Total weight (g) (along with rind and seed sacs)	363 $\pm$ 103.9 (190-600 gm)
Edible pulp portion (%)	54.3 $\pm$ 7.99
Rind portion (%)	36.5 $\pm$ 6.5
Number of seeds sacs	8 $\pm$ 2
Seed sacs portion (%)	15 $\pm$ 3.9

* average of 40 fruits.

Bael fruit lacks popularity as a table fruit due to its hard shell, excessive mucilage and large number of seeds, but has great potential for processing.

Extraction of pulp

Ripe fruit
↓
Wash in clean water
↓
Break fruit
↓
Scooping of pulp along with seed and fibre (discard peel)
↓
Addition of water equal to the weight of the pulp
↓
pH adjusted to 4.3 with citric acid (Titratable acidity 0.5 %)
↓
Knead
↓
Heat at 80^{o}C for one minute
↓
Pass through a pulping machine or stainless steel sieve of 20 mesh (discard seeds and fibres)
↓
Bael fruit pulp
↓
Canning, freezing or, more economically, preserving with 350 ppm SO_2 in the form of potassium metabisulphite

The semi ripe fruit has 6-10 seed sacs embedded in pulp and can be easily removed by a knife. The pulp removed of the sacs is less astringent. The sacs contain the mucilage, seed and fibre portion.

Preserve products with Bael fruit pulp

- Jam
- Squash
- Sherbet powder
- Toffees

Table 14: Amount of ingredients used in the preparation of different bael fruit preserved products

Name of the product	Water (ml)	Pulp (g)	Sugar (g)	Citric acid (g)	Skim milk powder (g)	Corn flour (g)	Glucose (g)	Cocoa powder (g)	Butter (g)	Cardamom (g)	Preservative	
											KMS	Sodium benzoate (g %)
Jam	--	100	40	0.2	--	--	--	--	--	--	--	0.1 g
Squash	100	100	150	2.0	--	--	--	--	--	0.4	0.25 g	–
Toffee	--	100	100	0.2	10	5	5	--	2.5	--	--	--
Cocoa toffee	--	100	100	0.2	10	5	5	2	1.0	--	--	--
Sherbat powder	--	100	100	0.2	--	--	--	--	--	--	0.35 mg	--

Preparation of jam

Bael fruit pulp
↓
Addition of sugar
↓
Boiling (with continuous stirring) the pulp
↓
Addition of citric acid
↓
Boiling to end point 63-70" brix
↓
Pouring into jars
↓
Cooling
↓
Waxing
↓
Capping
↓
Storage at ambient temperature

Preparation of Squash

Bale fruit pulp (measured to kept aside)
↓
Pulp measuring
↓
Preparation of syrup (heating just to dissolve)
↓
Straining the syrup
↓
Mixing syrup with fruit pulp
↓
Addition of preservative
↓
Bottling
↓
Capping
↓
Storage (Reconstituted (1:5) as and when required)

Preparation of bael fruit powder

Bale fruit pulp
↓
Preserved with 0.35 mg % of potassium metabisulphite
↓
Blended with sugar 30 %
↓
Dehydrated for 15-17 hours at 60^{o}C
↓
Pulverized to fine powder
↓
Addition of 0.2 g % of citric acid
↓
Stored (3 m)
↓
Reconstituted for use as cold drink
(1:5 powder to water dilution)

Preparation of toffee

Bale fruit pulp
↓
Concentrating pulp to 1/3rd volume by heating
↓
Addition of pulp with sugar, glucose and corn flour
↓
Transferring pulp to heated pan (butter smeared)
↓
Cooking to solid consistency
↓
Addition of milk powder and cocoa powder (dissolved in little water)
↓
Removing from fire
↓
Spreading the mass uniformly in 0.5 to 0.75 cm thick layer on a flat surface smeared with butter
↓
Cutting into pieces of suitable size
↓
Wrapping in butter paper
↓
Storing in dry jars

Bael fruit candy

The sliced bael fruit candy is one of the Thailand's favourite preserved fruit products

- Start boiling Bael fruit at $50^{o}C$ with 1:3 Bael fruit: Sugar syrup until the temperature ranges between $103^{o}C$ to $106^{o}C$. The time needed is about 3.5 hours. Syrup concentration should be increased about 10^{o} Brix per hour in 3 hour to reach $78\text{-}80^{o}$ Brix.
- Drying at room temperature ($30\text{-}35^{o}C$).
- The product is packed in poly stylene and nylone/LDPE stored at $4^{o}C$ and has a shelf life of 12 weeks (3 months)

Glycemic response of Bael fruit fibre

Experiment with non diabetic and NIDDM subjects revealed that incorporation of fruit fiber 12.5 g into the traditional recipe - plain Sambhar (150 ml) resulted in significant ($P < 0.05$) reduction of AUC, per cent glycemic response and blood glucose levels.

Non-diabetic subjects showed significant reduction of blood glucose levels at 2 hours interval whereas in NIDDM subjects ($P=0.05$) significant reduction was observed at all points. Hence, the prospects for expanded bael fruit processing are highly promising.

Caryota palm pith

Starch is a major renewable resources beside cellulose from plant kingdom and forms the chief source of Carbohydrate in the human diet. Sago palm is reported to be one of the cheapest and most readily available sources of food starch.

Productivity of the starch crops

Sago – 24 tons / hectare of starch per year
Rice – 6 tons / hectare
Corn – 5.5 tons / hectare
Wheat – 5 tons / hectare
Potato – 2.5 tons / hectare

Sago palm is considered to be a useful crop to cope up with predicted food shortage in the 21st Century as a source of Carbohydrate.

The principal genera exploited for starch production include Metroxylan, Arenga, Caryota, Eugessona and Corypha each differing in the yield and variations attributable to biophysical differences.

Caryota urens (Greek Word Karyotis = date)
Latin word Urere – To wither

It is considered to be indigenous to India, Srilanka and Malaysia and is found in large numbers in the moist forests of the Western and Eastern Coast and in the cool & shady valleys of Chota Nagpur and in Orissa, West Bengal and Eastern India. In Kerala, the palm is found in profusion. The palm is cultivated for preparation of sago, toddy use in jaggery making and fibre.

Palms for domestication or management

Scientific Name	Common Name	Native distribution and habitat	Major products	Comments
Caryota urens	Toddy palm or fish tail palm	South & South East Asia	• Sap to make sugar • Sap yields 20-27 litre / tree / day • Starch from stem • Yield : 100-150 kg/tree • Wine, alcohol, Vinegar.	• Numerous products • Informal cultivation practiced • Domestication potential in agro-forestry systems
Metroxlan Sagu	Sago	South East Asia	• Starch from stem • Yield 200-300 kg / tree • Leaves for thatching	• Palm is cultivated and managed successfully • Research by industry and FAO progressing well
Corpha umbraculifera	Talipotburi	South and South-East Asia	• Sap to make Sugar • Wine, alcohol, Vinegar • Sap yield zolities / tree / day • Starch from stem • Edible heart	• Domestication potential • Multipurpose palm with good mix of commercial and subsistence products

The sago is cooked in numerous native dishes often as a principal food during lean season in many parts of South India, particularly on the hilly regions.

The koyas and maria gond tribals of central India were reported to store pith of Caryota urens. Traditional products of the tribals with caryota palm pith are Ambali and roti (Pan cake).

Sago from Caryota urens is reported to be equal in quality to the best sago of commerce obtained from Metroxylan Sagu Rottb.

Comparison of Caryota sago with commercial sago specification of Rabbit brand (Malaysia)

Composition	Caryota palm sago	Rabbit beand sago (Metroxylan Sagu Rott b)
Moisture	15.4 %	11-15 %
Starch value	81.61 %	80-84 % min.
pH	7.0	6.0 – 7.0
Fibre	0.19 %	0.2 % max.

Extraction of starch from sago palm by traditional method

Tribals debark the trunk portion and cut it to small pieces, sundry and pound the pieces in stone pounder followed by sieving through fine cloth.

The principles and methods of palm sago extraction are similar for both subsistence and commercial production although the scale of operation is different.

Caryota sago thus extracted acts as thickener, gelling agent, crisp enhancer and has excellent baking qualities but its colour and astringent taste has limited trade value and prospects of its utilisation in food systems to its full extent.

Processing steps in purification of crude sago

Crude caryota sago
↓
Soak in solution containing 1 % sodium chlorite + 0.5 ml acetic acid (PH 5)
↓ Keep for 20 hours at room temperature
Filter through whatman No. 42 filter paper
↓

- Filtrate → Discard
- Filtered Sago
  ↓
  Washed with distilled water
  ↓
  Continue washings to PH 7
  ↓
  Dry sago at room temperature
  ↓
  Keep for 24 hours and powder evenly
  ↓
  Purified Sago (white and astringent free)

Physico-chemical characteristics of caryota palm with flour compared to corn flour

Quality characteristics	Caryota palm pith	Corn flour
Moisture, g %	6.7	10
Amylose, g %	16.7	25
Total starch, g %	64.0	71
Starch granule size, µm	44.0	15
Starch granule shape	Oval & spherical	Round, polygonal
Phenols, mg %	52	Nil
Bulk density, wt/vol.	0.72	0.68

- Caryota palm sago was shown to have medium amylose content i.e. 16.79 per cent, which is comparable with rice but lower than corn, sorghum and wheat.
- The onset of getalinisation for caryota palm pith and corn flour were 73°C and 76°C respectively whereas final gelatinization temperature occurred sharply for the sago (75°C) compared to corn flour (95°C). Hot paste spread was 5.2 cms for palm sago and 4.8 cms for corn flour.
- Caryota palm starch yielded a stiff gel and syneresis was not observed upon cooling and storing of gel.
- Bulk density of caryota sago was reported to be higher than corn.

The palm pith gel was yielded good quality gel with firm, viscoelastic texture and without syneresis upon cooling and storing of the gel.

***In vitro* starch digestibility (IVSD) of the sago products**

Name of the product	IVSD (%)
Bleached / Purified	3.01* ± 0.016
Sago noodles	62.9* ± 1.57
Sago gel	32.2* ± 0.80
Sago biscuits	9.40* ± 0.23
Sago ambali (porridge)	14.62
Porridge (sago + ragi flour)	34.50
Roti (Pan cake)	43.40
Biscuits	7-9.36

Values with * are significantly ($P < 0.05$)

Starch digestibility varies among products due to many factors such as

- Number of glucose units
- Degree of gelatinization
- Granule particle size
- Amylose / amylopectin ratio
- Starch protein interaction
- Amylose lipid complexes
- Percentage of resistant or retrograded starch

Products with purified caryota palm sago

Purified sago was used at different levels of incorporation for the development of processed products i.e. biscuits (60 %), gel (100 %) and noodles (60 %). Results indicated higher acceptability scorer for the products for all the sensory attributes.

Preparation of gel

- A slurry was made with combination of water, sago and powdered sugar and heated to a temperature of 72^{o}C
- The hot paste was poured into gel moulds and allowed to set

Preparation of sago noodles

- Caryota sago was pregelatinized to a temperature of 50^{o}C using 90 ml of water to which wheat flour and fat were added.
- The contents were kneaded to dough consistency for 10-15 minutes.
- The dough was passed through easy kitchen press to obtain noodles, 1 mm in diameter and 180-200 mm in length.
- These noodle are then dried in an oven at 40^{o}C (to retain the creamy colour) for 17 hours to a moisture level of 10 %.
- The noodles were stored in air tight polythene bags

Cooking of noodles

- Noodles were cooked for 2-3 minutes in two cups of boiling water containing ½ tsp of salt and a few drops of cooking oil.
- The cooked noodles were strained through a plastic sieve and held under cold running water for few seconds to avoid stickiness

Caryota palm pith

- thickener, binding agent
- stabilizers,
- texturizers,

- fat replacer/enhancer
- encapsulation agents
- gelling agents,
- film farmer,
- moisture barrier and
- crisp enhancer.

Hence caryota palm sago has a potential for commercial value.

Phenolic compounds and amylase inhibitor units (AIU) in caryota sago

Components	**Caryota sago**	
	Crude	**Bleached**
Total phenols (mg %)	52.5 ± 1.63	53.42 ± 0.68
Type of phenolics (mg %)		
Catechin	0.071 ± 0.005	0.0297 ± 0.001
Epicatechin	0.0432 ± 0.002	0.0329 ± 0.005
Quercetin	0.0258 ± 0.001	0.0033 ± 0.0004
Gallic acid	0.01365 ± 0.00	n.p.
Tannic acid	0.0219 ± 0.001	0.0158* ± 0.001
Condensed Tannins (CE %)	0.0004 ± 0	0.0001* ± 0
Amylase inhibitor units (AIU)	884	881**

Significant at $P < 0.05$

Utilisation of sago starch

Food Industry	**Biotechnological Industry**	**Non food industry**
Confectionery	High fructose syrup	Biodegradable plastic
Sago pearl	Glucose syrup	Textile
Bread making	Dextrose monohydrate	Paper
Desserts	Caramel	Adhesive
Noodles	Maltose	Plywood
Crackers	Maltodextrin	
Modified starch	Sweeteners	
	Monosodium glutamate	
	Sorbitol	

Bio-sweetner : Stevia

Stevia Rebaudiana Bertoni is a slender perennial herb native to the North Western regions of Paraguay and widely distributed over all the world.

Bio-sweetner : Stevia

- Calorie free
- 100 times sweeter than cane sugar – in natural state
- 300 times sweeter when processed.

Calorie free Bio-Sweetener of high quality

Medicinal properties of Stevia

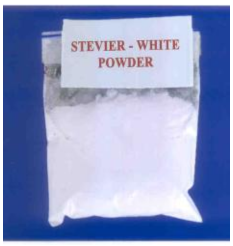
- Regulation of blood sugar
- Prevention of hypertension
- Treatment of skin disorders
- Weight management
- Prevention of tooth decay

Preparation of Stevia extract

Powdered Stevia (green) (25 gm)
↓
Luke warm water (500 ml)
↓
Simmering on low heat (2 hours)
↓
Thick extract (condensed to 100 ml)
↓
Filtering after 12 hours
↓
Stevia liquid extract
↓
Add 1-2 drops of food grade alcohol as preservative

Commercial stevier products

Stevier White powder	Stevier Brown powder	Stevier Whole leaf powder	Stevier Whole leaf liquid extract



Incorporation of stevier products in beverages

Products	Acceptable levels of incorporation			
	Stevier-whole leaf powder (g)	Stevier-white powder (g)	Stevier-brown powder (g)	Stevier-whole leaf liquid extract (ml)
Cold Beverages (per 200 ml)				
Badam Milk	0.3	0.3	0.2	0.2
Banana Milk Shake	0.3	0.3	0.3	0.2
Chocolate Milk Shake	0.3	0.3	0.3	0.2
Grape Juice	0.4	0.4	0.3	0.3
Lemon Juice	0.3	0.3	0.2	0.2
Hot Beverages (per 200 ml)				
Ragi Java	0.3	0.3	0.3	0.3
Coffee	0.2	0.2	0.2	0.1
Masala Tea	0.2	0.2	0.2	0.1

Incorporation of stevier products in baked foods

Products	Acceptable levels of incorporation			
	Stevier-Whole leaf powder (g)	Stevier-White powder (g)	Stevier-brown powder (g)	Stevier-whole leaf Liquid Extract (ml)
Baked Foods (No. of prepared products : 18)				
Sweet Biscuits	5	5	5	4
Cup Cakes	3	3	3	2.5

☞ In all the beverages 100 per cent substitution of stevier products in place of sugar was found to be satisfactory.

☞ In baked products all the stevier products were acceptable at 100 per cent substitution to sugar in sweet biscuits and 50 per cent substitution in case of cup cakes

Additional benefits

☞ Stevia lowered the energy values of the products

☞ It was reported that there was 25 per cent decrease in the calorie content of stevier incorporated products

Baby corn / Mini corn / Vegetable corn is an innovation in maize research

Baby corn – Young tender flowering maize ears harvested within 2-4 days after white silk emergence before fertilization.

Physico-chemical and sensory characteristics of baby corn

Parameters		
Total weight, g	:	53.80 ± 0.31
Dehusked weight, g	:	11.50 ± 0.58
Length of dehusked cob, cm	:	7.00 ± 2.00
Width of dehusked cob, cm	:	1.50 ± 0.70
Weight of husk and silks, g	:	42.30 ± 0.73
Colour	:	Creamish yellow
Flavour	:	Sweet subtle
Texture	:	Crisp/tender
Shape	:	Vertical (finger like)
Moisture, g	:	88.10 ± 0.30
Protein, g	:	1.90 ± 0.05
Carbohydrate (by diff.), g	:	4.0 ± 0.02
Fat, g	:	0.20 ± 0.01
Fibre, g	:	2.41 ± 0.04
Ash, g	:	0.46 ± 0.01
Calories, kcal	:	30
Total sugars, mg	:	415 ± 0.063
Reducing sugar, mg	:	300 ± 0.270
Potassium, mg	:	158.50 ± 0.59
Calcium, mg	:	23.45 ± 0.19
Iron, mg	:	1.97 ± 0.07
Thiamine, mg	:	0.06 ± 0.01
Riboflavin, mg	:	0.15 ± 0.01
Ascrobic acid, mg		25.2 ± 0.91

Baby corn is used in preparing a wide variety of traditional and intercontinental dishes besides being canned

Incorporation in traditional Indian Snacks & Savouries like Vada, Kofta, Finger fry, Roti, Raita; and Sweets : Burfi, Kheer, Kesari, Halwa found to be quite acceptable.

Preparation of preserve product – pickle with baby corn

Cut dehusked cobs into ½” pieces

↓

Shallow fry to 1-2 min (till they become golden brown)

↓

Mix a little lime juice and keep a side

↓

Prepare a spice mixture with chilli powder, salt, mustard powder, fenugreek powder, garlic pods, cloves

↓

Add the spice mixture to cut pieces

↓

Finally add sesame / groundnut oil

↓

Store in airtight glass bottles

Baby corn being low in fat, carbohydrate and rich in fiber can be referred for those who are weight conscious. Baby corn, an upcoming vegetable, can bring dietary diversity and value addition to products of specific dietary importance

Dillenia indica (Hindi – Chalta)

Dillenia indica is found in Sub Himalayan tract from Kumaon and Garhwal eastwards to Assam and West Bengal and in many parts of South India

Food uses

Flavoring agent, Jam and Jelly

Preparation of Dillenia Fruit Squash

Method A

Ripe fruit

↓

Washing in Clean Water and Drying

↓

Cut into Fruit Pieces (2 kg)

↓

Cook with water (1 litre)
Under pressure of 7 kg for 15 minutes

↓

* Add Sugar (1 kg)
+
* Citric Acid (30 gms)
+
Benzoic acid (2.5 gms)
+
Yellow colour (2 drops)

↓

Squash (1 litre)

Shelf life of six months

* alternate proportions of sugar and citric acid 800 g : 20 g or 600 g : 10 g

RADIATION PROCESSING OF FOOD: APPLICATION, CURRENT STATUS

& FUTURE PERSPECTIVE

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ANGRAU

Executive summary

Trade in food and agricultural products is important to all countries; the economies of many developing countries would significantly improve if they were able to export more food and agricultural products. Unfortunately, many products cannot be traded because they are infested with, or hosts to, harmful pests, contaminated with microorganisms, or spoil quickly. As a result, many developing countries cannot build strong economies and consumers do not have access to the wealth of foods and products that couldcontribute to health and enjoyment of life. Foods contaminated with microorganisms cause economic losses, widespread illness and death.

Several technologies and products have been developed to resolve problems in trading food and to improve food safety, but none can provide all the solutions. Some chemical fumigants currently in use are harmful to people and/or the environment. Other technologies, such as controlled atmospheres, may require special equipment or storage facilities that are expensive. Regulatory approval is also an issue when controlled atmospheres are used for pest control. Heat treatments such as canning are commonly used to resolve problems such as bacterial contamination or short shelf-life. Canned foods are very different from the original product; some have excellent consumer acceptance, others may not be rated as highly as fresh products. Certain heat treatments sometimes damage fruit.

Irradiation is an effective technology to resolve technical problems in trade of many food and agricultural products, either as a stand-alone technology or in combination with others. As a disinfestation treatment it allows different levels of quarantine security to be targeted and it is one of few methods to control internal pests. As a disinfection treatment it offers good, broad spectrum control of many pathogenic and spoilage organisms with minimal change to the food. The ability of irradiation virtually to eliminate key pathogenic organisms from meat, poultry and spices is an important public health advantage. The huge number of cases of illness and death from pathogenic bacteria in meats and poultry represents a terrible waste of human and economic potential, particularly when a technology that could prevent a large percentage of such cases is available. Irradiation also offers clear advantages over chemical and heat treatments for spices, in terms of bacterial control and maintenance of organoleptic properties. Since spices are so widely used in processed foods, this beneficial effect of irradiation is multiplied. In addition to controlling pests and eliminating harmful bacteria, irradiation also extends the storage life of many foods; this effect makes irradiation particularly useful for tropical fruits, commonly infested and also requiring extended shelf-life to reach consumer markets in good quality.

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Although, irradiation is often clearly a superior technology, there are constraints that restrict its use, including lack of regulatory approvals, labeling issues and lack of consumer information and understanding. Harmonization of sanitary and phytosanitary measures has been negotiated intensely under the Uruguay Round of the General Agreement on Tariffs and Trade (GATT), and two technical trade agreements on the Application of Sanitary and Phytosanitary Measures (SPS), and on Technical Barriers to Trade (TBT) were agreed upon. An important principle, that of equivalence, was also agreed to in these negotiations. In the ambit of these agreements the governments will be obliged to accept measures which can achieve the same results. This principle will result in greater acceptance of irradiated foods in international trade. In summary, measures to handle technical or pest problems should not be more trade restrictive than necessary to achieve a legitimate protection objective. To ensure that the national regulations withstand the inevitable court challenges, efforts should be made to ensure that no discrimination against irradiated food, processed according to the principle of the Codex Standard, is introduced into national regulations. Regulations on food irradiation vary widely from broad acceptance of several food classes to limited acceptance of a few food items, and from prohibition to complete silence on the subject. Such disharmonious regulations are barriers to trade in irradiated foods.

Background

Global attention to food insecurity and malnutrition began in the 1930s leading to the establishment of the Food and Agriculture Organization in 1945. Safeguarding harvests from pests and spoilage though essential, was often neglected. Considerable post-harvest losses lead to a significant loss of valuable produce; waste of production resources (water, land, labour, etc.); sub standard quality and high prices. Any technology used to control post-harvest losses should fit into existing social and marketing systems, be cost effective and provide better-quality, and safe products for consumers. Consumers are now looking for 'clean' food, with minimal use of additives and little or no pesticide residue. Irradiation is an effective, broad-spectrum, residue-free, widely researched technology. It controls insect infestation, inhibits the germination of root crops, and prolongs the shelf-life of perishable produce. International standards to ensure the safety of irradiated products and to facilitate trade have been recommended by the Codex Alimentarius Commission which is recognized by the World Trade Organization (WTO). Good Irradiation Practices (GIPs) for a broad range of applications have been developed and widely disseminated by the International Consultative Group on Food Irradiation (ICGFI). Expertise in irradiation processing exists in a network of centers around the world, many of them in developing countries. At present, 41 national governments have regulations which permit commercial applications of food irradiation. Irradiation can play an important role in achieving the food security goals of developing countries. In addition, it can serve the mutual interests of developing countries and more industrialized societies by assisting the expansion of agricultural trade. Traditionally food security concerns gave highest priority to increasing agricultural production and productivity with little attention to increased efficiency in product utilization. Food security now requires increased production and protection of the harvests through efficient storage, processing, and distribution. Only recently, agriculture ministries and international organizations have recognized the impact of urbanization on the food system and the significant contribution of an efficient post-harvest sector to the overall economy, employment and adequate, nutritious food supply.

Priority for protection of the produce is needed because of **significant post harvest losses**, **wastage of resources** (production resources like water, land and labour, negatively affecting agriculture sustainability e.g. through land erosion, soil degradation and increased applications of pesticides and fertilizers.), **monetary loss**, **negative consequences** like :

- costly rejections of agriculture and fisheries products by export and tourism markets and the consumers in domestic markets.
- higher prices for those who can least afford an adequate, safe and nutritious food
- adulteration of staple foods by unscrupulous marketers seeking prolonged shelf-life for their products.
- smuggling of high demand fruits and vegetables which would disseminate harmful pests.

Chemical based treatments though more convenient, less expensive and do not require well trained personnel are being challenged because of :

1. Safety Concerns

Toxicological and occupational safety reviews have led to the banning or phasing out of some chemical treatments, e.g., ethylene dibromide (EDB), was banned in the 1980s as a fumigant for fresh fruits and vegetables. Ethylene oxide (ETO) has been banned in most major food importing countries and is also being reviewed in others as a decontamination fumigant for spices, cocoa beans and grains. Phosphine, the only fumigant (other than methyl bromide) widely registered and used, is toxic, flammable, reacts with some metals, and is relatively slow acting.

2. Environmental Concerns

Methyl Bromide (MB), the most extensively used fumigant for food and other agricultural applications, may suffer the same fate as EDB. Methyl bromide is listed under the 1991 Montreal Protocol as an ozone-depleting substance and is to be phased out of production and use in industrialized countries and its use to be frozen in developing countries in the next few years. An extensive search for alternatives to MB is under way, including the consideration of irradiation for controlling insect infestation and quarantine pest problems.

3. Emerging insect resistance to phosphine and other conventional insecticides.

4. Consumer Acceptance

New technologies, such as food irradiation, the use of growth hormones and transgenic plants, are difficult to introduce owing to consumer confusion regarding their safety, benefits and limitations. Perceived public concern, rallied by advocacy groups and the media, has delayed regulatory approval and the commercial use of food irradiation. However, market trials have demonstrated that consumer reluctance has decreased remarkably when consumers have had the opportunity to purchase irradiated foods and experience the benefits. A good example of government leadership in this aspect has been the development of regulatory policies for the use of irradiation as a phytosanitary treatment by the Animal and Plant Health Inspection Service (APHIS) of the US Department of Agriculture (USDA). The North American Plant Protection Organization (NAPPO) has issued a phytosanitary standard based on the APHIS document which has led to the adoption in 1996 by the USA of an irradiation regulation to allow the treatment of certain Hawaiian fruits (e.g. papaya, carambola, lychee) prior to marketing in the mainland USA.

5. Regulatory acceptance

Approval of a new treatment requires extensive technical documentation to demonstrate efficacy and safety of the treatment, particularly when political and other pressures are exerted. The need to find economic alternatives to chemical treatments has become a priority to many governments and international plant protection organizations. Irradiation, a physical treatment, is an alternative phytosanitary measure being actively considered.

Issues of current and new technologies

Food preservation technologies aim to reduce losses, control foodborne pests and diseases, and retain original quality and nutritive value. No single technology is suitable for all applications. All preservation methods reduce product quality to some extent. Every technology has advantages and limitations, but may act in a complementary way with other technologies to give better result. Identifying the comparative advantages of competing technologies or combinations of treatments is the challenge for technologists, marketers and consumers. The World Health Organization (WHO) (1987) summarizes advantages of the irradiation technique over conventional food processing methods in that it has valuable features like :

- it being physical process which leaves no residue
- it preserves solid foods, as pasteurization preserves liquid products
- it is a 'cold' process, applicable to chilled and frozen foods
- it is a relatively low-cost, broad-spectrum, low-energy alternative to canning, freezing, and dehydration
- irradiation processing permits the conservation of foods in the fresh state
- foods can be treated after packaging.
- it can complement other technologies, particularly refrigeration; and
- it is particularly efficient for high throughput, free flowing products, such as grains.

Irradiation has been proven effective and safe to use in several commercial applications, e.g. delaying the germination of root crops; delaying the ripening of fruits and vegetables; controlling insect infestation in cereals and pulses; and as a treatment for quarantine pest problems. These 'food security' applications can be achieved with low doses of irradiation of 1 kiloGray (kGy) or less. The Codex General Standard for Irradiated Foods recognizes the safety and effectiveness of food treatments up to an overall dose of 10 kGy. Standards and related texts established by the Codex Alimentarius Commission are recognized by the World Trade Organization (WTO) in the Agreement on the Application of Sanitary and Phytosanitary Measures. Although countries may impose more stringent standards than provided by the Codex, there needs to be a scientific justification for any restriction to trade. The World Health Organization (WHO) views irradiation as a process which has the potential to increase the supply of safe food, and contribute to improved public health. The Food and Agriculture Organization (FAO) sees food irradiation as a process to reduce food losses and facilitate trade. It would appear difficult for a country to ban the import of irradiated foods without the risk of being challenged.

Approval in India

In recognition of the safety of this technology the Ministry of Health and Family welfare, Govt. of India, by a Gazettee Notification in August 1994, amended the Prevention of Food Adulteration Act (1954) Rules and approved irradiation of onion, potato, fruits, vegetables and spices for domestic market and export. Additional items were approved in April 1998 and in May 2001. In India commercial food irradiation could be carried out in a facility licensed to do so. The license could be obtained after fulfilling the requirements of the Atomic Energy regulatory Board (AERB). Today some 40 countries worldwide including

India have approved the use of food irradiation for over 100 food items and about 30 of them are applying the technology on a limited commercial scale.

The Ministry of Food Processing Industries (MOFPI) is promoting radiation processing technology as a means of preservation of perishable foods and enhancement of quality. The MOFPI has taken an initiative and proposed an Act to provide a single window system and move from regulatory penal regime to that of promotional and developmental mechanism so as to sub serve the interest of the Indian Food Industry and to make it viable and competitive and derive the best advantage of globalization of the markets. The MOFPI is also encouraging State Governments, PSUs and entrepreneurs in setting up of facilities for radiation processing of foods. There is however, a need to bring awareness by practical demonstration of the food irradiation process on commercial scale to farmers, traders, cooperatives, marketing personnel and public at large. Need is also there to develop protocols through R & D for different foods of different regions for improving their shelf life and sanitization.

These developments have opened up numerous possibilities for expanding trade both national and international in safe and high quality food commodities. Economic survey in the country shows significant post harvest food losses. Huge buffer stocks of grains, especially wheat, are being built up. With little scope for storage, around 3 million tons of food grains are lost every year due to insect and pests alone. With progressive increase in quantity and storage period of food grains these losses are likely to escalate further unless disinfestation methods are improved. Traditional methods of preservation by use of chemicals are gradually being phased out . Some of the countries like USA, Japan and many in Europe have already banned the use of several common fumigants.

Consumers are increasingly becoming aware of the potential microbiological hazards in food and are calling for effective food safety controls. Recent attention has been invited towards presence of enteric pathogens like *Campylobacter, Shigella, Vibrio, Aeromonas, Escerichia coli , Salmonella* species, *Listeria monocytogenes* and other pathogenic bacteria in food that are primary cause of food borne illnesses. There have been several instances of rejection of frozen shrimps exported from India to foreign markets due to the presence of Salmonellae. Several meat and fish borne parasites cause disease in man due to consumption of raw or improperly cooked meat and fish. Some important examples are cysticercosis caused by bovine and pork tape worm *Cysticerus spp*., toxoplasmosis caused by *Toxoplasma gondii* in beef, mutton, pork; trichinosis caused by *Trichinella spiralis* in pork. These parasites along with some other parasitic protozoa and helminthes are of enormous public health significance. This has emphasized the need for expanding food safety programs . Government regulators, public health authorities, health professionals, scientists, consumer groups and the food industry all agree that prevention of food borne illness is a primary food safety goal. These factors are the driving force behind the need for a new technology which can provide an environment friendly alternative to toxic fumigants and can deliver safe food with extended shelf life. The upsurge in the interest in food irradiation by national authorities and industry may be attributed.

1. Increasing concern over foodborne diseases and uses of certain chemicals in food.
2. High post-harvest food losses from insect infestation, microbial contamination, and spoilage
3. Stringent regulations related to quality and quarantine in international trade in food products.

Irradiation and Trade in Food and Agricultural Products

Conservative estimates put post-harvest losses in food and agricultural commodities in India between 20-50 percent, which are worth thousands of crores of rupees. These losses are primarily due to insect infestation, microbiological contamination, and physiological changes due to sprouting, ripening and senescence. Conventionally, post-harvest losses have been prevented by techniques such as cold storage, fumigation, and drying.

Radiation technology can complement and supplement existing technologies to ensure food security and safety. It provides effective alternative to fumigants that are being phased out due to their adverse effects on environment and human health. Radiation processing technology can be used for:

- Disinfestation of food grains and pulses
- Inhibition of sprouting in bulbs and tubers
- Extending shelf-life under recommended conditions of storage
- Ensuring microbiological safety
- Overcoming quarantine barriers to international trade

The technology can also be used for hygienization and sterilization of nonfood items including cut-flowers, pet food, cattle feed, aqua feed, ayurvedic herbs and medicines and packaging materials. Radiation processing technology has been developed through worldwide R&D efforts of more than four decades. India is one of the few countries in the world having the necessary expertise and know-how for deployment of this technology. Radiation processing involves controlled application of energy of ionizing radiation such as gamma rays, x-rays, and accelerated electrons.

Safety

The process is approved by the international bodies including WHO, FAO, IAEA and Codex Alimentarius Commission. More than 40 countries have approved the process for more than 100 items of food. First approved in India in 1994, today more than 20 commodities are approved by Directorate General of Health Services under the Prevention of Food Adulteration (PFA) Act Rules. Processing is carried out in plants approved by the Atomic Energy Regulatory Board and local Food and Drug Administration.

Technology Demonstration Units Radiation Processing Plant at Vashi, Navi MumbaiTwo technology demonstration units have been set up by DAE, one at Vashi, Navi Mumbai, for application of high doses for commodities such as spices and dry vegetables (30 tonnes/day), and another at Lasalgaon near Nashik (Maharashtra) for commodities such as onion (10 tonnes/day), cereals, pulses and their products, and cut-flowers requiring low dose irradiation. Entrepreneurs in private and co-operative sectors have shown interest in setting up radiation processing plants. A women's NGO, Annapurna Mahila Mandal is selling radiation-processed spices in and around Mumbai. There is a need to deploy and integrate this technology with the national system for procurement, storage, distribution, and marketing of agro-produce. Radiation processing plants designed to process several products requiring specified range of radiation doses need to be set up in private, co-operative, and public sector.

Applications of Radiation Processing

Low dose applications (Less Than 1kgy)

Inhibition of sprouting in potato and onion Insect disinfestation in stored grain, pulses and products

Destruction of parasites in meat and meat products

Medium dose applications (1-10 kGy)

Elimination of spoilage microbes in fresh fruits, meat and poultry
Elimination of food pathogens in meat and poultry Hygienization of spices and herbs

High dose applications (above 10 kGy)

Sterilization of food for special requirements
Shelf-stable foods without refrigeration

[Gray is the unit of radiation absorbed dose = 1Joule/kg. The old unit of dose is rad (1Gy = 100 rad)

Items of Food Permitted for Irradiation under Indian Prevention of Food Adulteration (PFA) Act Rules

S.No	Name of the food	Dose of Irradiation (kGy)		Purpose
		Minimum	Maximum	
1.	Onion	0.03	0.09	Sprout inhibition
2.	Potato	0.06	0.15	Sprout inhibition
3.	Shallots (small onion), garlic and ginger	0.03	0.15	Sprout inhibition
4.	Rice	0.25	1.0	Insect disinfestation
5.	Semolina, wheat atta and maida	0.25	1.0	Insect disinfestation
6.	Pulses	0.25	1.0	Insect disinfestation
7.	Dried sea- food	0.25	1.0	Insect disinfestation
8.	Raisins, figs and dried dates	0.25	0.75	Insect disinfestation
9.	Mango	0.25	0.75	Shelf life extension and quarantine treatment
10.	Meat and meat products including chicken	2.5	4.0	Shelf life extension and pathogen control
11.	Fresh sea food	1.0	3.0	Shelf life extension
12.	Frozen sea food	4.0	6.0	Microbial pathogen control
13.	Spices	6.0	14.0	Microbial decontamination

What needs to be done further ?

The users agencies under the Ministries of Agriculture, Civil Supplies and Consumer Affairs and Commerce (Agricultural and Processed Food Products Development Authority, different commodity boards, Marine Product Export Development Authority), as well as private entrepreneurs ought to perceive the need for application of this technology on commercial scale. There is also a need to amend rules and regulations for adopting and expanding use of this technology. For example, the quarantine regulations need to be amended for application of the technology for export or import of agro-horticultural produce.

Availability and economics of irradiation facilities

There are more than 120 commercial food irradiation facilities world wide, spread over

developed as well as developing countries. Three types of irradiation systems are internationally approved for the pasteurization, shelf-life extension and/or preservation of food - gamma technology mainly using cobalt-60, electron beam accelerators and X-rays. A variety of designs of each of these facilities exist to meet the need of customers. Gamma Irradiators expose food to high-energy photons, emitted during the decay of cobalt 60 radioisotope sources. System designs vary but in all cases, time is the key parameter to controlling the absorbed dose. They feature excellent penetration capability, reliability and flexibility. Total capital costs for a gamma irradiation facility will vary depending on the

a) processing requirements of the packing densities,
b) handling and distribution conditions,
c) dose uniformity needs,
d) throughput requirements,
e) local economic and regulatory conditions.

A cost range of US$3 to US$6 million for the equipment and cobalt is normal for this type of irradiator. In Electron Beam (E-beam) and X-ray processing, foods are exposed to a high-energy stream of electrons, generated in/by an electron accelerator. X-ray equipment further focuses these electrons onto a metal target of high density. The electrons or X-rays (photons) produced, react in the same manner as gamma technology, i.e. disrupt the DNA bonds in the microorganisms present on the food, and effectively eliminate these pathogens. Electron beam systems deliver the intended dose in a very rapid manner, but have low depth/ density penetration capability. X-ray systems deliver the intended dose with time and penetration ability more like a gamma system, both of which can penetrate final food cartons measured in many inches in depth. Pricing of accelerator/X-ray systems, including all the ancillary equipment necessary to run them, range from US$5 to US$10 million depending upon individual-based factors.

Trade prospects

The international phasing out of MB as an ozone-depleting substance will most critically affect the need for alternative technologies for pest control. Quarantine and pre-shipment uses of MB are currently exempt internationally, although there is no exemption for these uses under the Clean Air Act in the USA. Developing countries are on a delayed time schedule for the phase-out of MB. There are many foods and agricultural commodities that will require new treatments and approval for the use of newtreatments. Irradiation is one of the most ready and effective pest control treatments. If regulatory approvals by leading importing countries such as the USA continue, irradiation has the potential to become a very important alternative to MB. On the other hand, the poor level of official regulatory acceptance of irradiation by other major importing nations such as Australia, Canada and Japan negatively affects its use for many exports. It is important to ensure harmful bacteria are eliminated from meat, poultry and marine products. Irradiation is already used as a means to eliminate harmful bacteria in these foods, enhancing trade and reducing economic risk with these commodities. However, there is an urgent need for many countries to acknowledge that irradiation is either needed or already used for these foods and to improve their regulatory acceptance.

Ethylene oxide (ETO), an important fumigant for the disinfection of spices, herbs and dry ingredients, has come under increasing pressure from regulatory authorities on both human health and environmental grounds. It has been banned in the European Union in 1991 and is under review in the USA. Irradiation is the most likely and effective alternative to ETO, although heat treatments are in use for some products.. There is a need for improved availability of irradiation equipment in spice producing countries. Over the past five years, irradiation equipment has become more readily available for research and commercial use. Equipment must be available for food industry applications research for irradiation to be better used. New equipment designs will be needed to better fit irradiation into some commodity and infrastructure applications as other competitive technologies such as chemical fumigants are phased out.

Over 40 countries have regulations in place to allow trade in irradiated food. Spices and dried vegetable seasonings are the most common foods irradiated commercially both in volume and the number of countries involved. More than 20 countries have irradiated spices for commercial purpose and the volume has increased to over 80,000 metric tonnes in 1999. Some of these irradiated spices and dried vegetables seasonings have already entered international trade. Other commodities that have the potential to be traded internationally include irradiated fresh and dried fruits, nuts, poultry, meat, seafood, cereals and pulses, condiments including coffee, cocoa beans and tea. Some of these commodities are already traded in the countries in which they are irradiated. International trade depends on compatible regulations among countries that are trading partners. As regulations on food irradiation in an increasing number of countries are harmonized, international trade in irradiated commodities will be greatly facilitated. The provisions of the SPS Agreement of the WTO may also reduce barriers to trade in irradiated foods.

Radiation Processing Plant as a Contract Facility

The radiation facility will bring in almost cash business. Since material is brought in by clients, investment in the material or their price fluctuations do not bother facility provider. Generally payments are made against delivery. One can also do backward and forward integration of the facility. A food park can be built around it with various processing, packing, warehousing, transport and container facilities. The facility can also be made part of a cold chain. When many such irradiation facilities are set up Government might associate the entire public distribution system with radiated food. The irradiated packed food would avoid contamination, adulteration and pilferage of the food and would avoid exploitation of the poor.

For co-operatives and contract farming firms it will provide marketing opportunity as selling at right location at the right time would bring in better profits. The following table gives the market potential for an irradiation facility.

Product	Total Production (tons/year)	Exports (tons)
Onion	4,900	2,16,000
Potato	25,000	7,873
Wheat	70,000	12,36,000
Rice	86,800	7,18,000
Mango and pulp	10,811	89,000
Marine	5.5 million	2,38,000
Meat	5,000	1,670
Spices	11,334	1,32,000

Source: National Horticulture Board and CII

THE ECONOMICS

The persons desirous of setting up such facility should know their strengths and weaknesses. In this competitive world one should release that market is first Manufacturing / service is next. In India till today one company does not have sufficient product at one location to have it own captive irradiation facility. Hence one has to decide about the availability of various products, their season and available quantity to select right product mix. The products selected should be available in the right quantity at various time of the year so as to keep the plant operational through out the year and generate sufficient revenue.

The logistics is also very important. The plant can be near the producing market or near the consuming market and availability of other infrastructures like accessibility, power, water etc, are very important.

It is a capital-intensive venture. One million Ci. Gamma irradiation facility would require an investment of about Rs. Six to Seven Crores to begin with the Co-60 source of 200 kCi. This is a green field project so banks do not have precedents to fall back up on. Co-60 source also does not have any resale market value and hence banks are not ready to consider it is necessary to raise loan with large moratorium period and low rate of interest. Facility loaded below 200 kCi is commercially non-viable, unless associated with trading.

It the product range involves very large dose variation the selection of right type of conveyor becomes an important consideration. Generally products should be selected such that their dose requirement falls in the very low dose to medium dose range or medium dose to high dose range If one wants to irradiate onions and potatoes, then irradiation of medical products should not be aimed in the same plant. As the source strength is increased, for very low dose products, the conveyor maximum speed becomes restricting factor.

Overcoming Trade Barriers

As of May 1998, the following countries became members of ICGFI: Argentina, Australia, Bangladesh, Belgium, Brazil, Bulgaria, Canada, Chile, Costa Rica, Côte d'Ivoire, Croatia, Cuba, Czech Republic, Ecuador, Egypt, France, Germany, Ghana, Greece, Hungary, India, Indonesia, Iraq, Israel, Italy, Republic of Korea, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Pakistan, People's Republic of China, Peru, Philippines, Poland, Portugal, South Africa, Syrian Arab Republic, Thailand, Tunisia, Turkey, Ukraine, United Kingdom, United States of America, Viet Nam, and Yugoslavia.

The following specific actions are now urgently required by ICGFI member governments to overcome non-tariff trade barriers in irradiated foods:

1. Harmonization of national regulations on food irradiation based on the Codex Standard and Model Regulation endorsed by ICGFI. Individual ICGFI member governments should support the proposed revised Codex General Standard for Irradiated Foods.
2. Initiate a procedure to develop an international standard on irradiation as a phytosanitary treatment of fresh and processed horticultural commodities.
3. Petition major food importing governments which have not approved a wide use of food irradiation, eg. the EU (by concerted efforts of developing countries) to expand the "Community List" of irradiated food to be traded within and into the EU.
4. Research that will provide regulators with information upon which to base policy decisions, and provide the food industry with information relating to commercial issues, is needed to improve regulatory approvals and trade in irradiated foods.
5. Inform the WTO through its SPS Committee of actions taken on these issues.
6. The mandatory labeling of irradiated foods when competitive treatments (such as fumigation) do not require labeling is an unfair barrier to trade, increases costs and inhibits industry. Labeling for the consumer level should be voluntary. Where irradiation is used to resolve technical constraints to trade its use should be notified in documentation available to industry and trade officials.
7. Providing good information to consumers is the responsibility of every link of the marketing chain. Governments approving irradiation to improve trade should defend their decision, discussing the factors that led to approval, and the benefits to the country, industry and public of improved trade measures. Industry should discuss more openly the requirements of food handling so consumers have a fuller understanding of the realities of agriculture and food processing.

In closing, it can be stated that food irradiation is not a miracle process that can convert spoiled food into high-quality food. It is equally true that not all foods are suitable for radiation treatment, just as not all foods are suitable for canning, freezing, drying, etc. Radiation processing technology can therefore, strengthen nation's food security, improve food safety and boost export of agricultural commodities. The time is now most favorable to exploit this technology with initiative to integrate the technology with national mainstream.

TECHNOLOGY OF CONVENIENCE FOODS

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Packaged foods that require minimal / no cooking or processing operations prior to eating / consumption are called convenience foods.

- Most of the processing operations like cleaning, grinding, blending, roasting and cooking of various ingredients are done at the manufacturer's end prior to packing.
- Convenience Foods require either simplify heating in case of "HEAT-n-SERVE" Foods and simple, easy operations like re-constitution or boiling or frying or toasting prior to eating in case of "Ready to Prepare" Foods.
- No special culinary expertise is required to cook and serve any convenience food.
- Convenience foods have a fairly long shelf-life varying from 3 months to 12 months.

CHAKKI ATTA

Wheat
↓
Cleaning
↓
Washing
↓
Blending
↓
Conditioning (12 % moisture)
↓
Chakki Grinding
↓
Sieving
↓
Fortification
↓
Packing
↓
Secondary packing

- Out of 33 varieties of wheat grown in India, only 14 are suitable for Chapati making.
- Varieties are LOK1/SUJATA/Kalyan Sona/RAJ 1482 / PBW343/GW273/GW 496/HW 2004.
- Protein content varies from 10 to 12.5 %.
- Shelf-life : 4 months when packed in PET / Poly laminates.

CONVENIENCE FOODS

Ready to Prepare

- Chakki Atta (1100 Cr)
- Instant Food mixes (600 Cr)
- Culinary Pastes

Beverage Mixes

Frozen Foods

- ➢ Batter / Dough
- ➢ Vegetables
- ➢ Meat / Fish / Poultry

Ground / Blended Masalas

Infant Foods (1000 Cr)

Malted Milk Beverages (1350 Cr)

Soup Mixes

Ready to Eat

- Breakfast Cereals (200 Cr)
- Heat-n-Serve Foods (100 Cr)
- (Ready Meals)
- Self-Heating RTE Meals

Baked Foods

- ➢ Bread (1000 Cr)
- ➢ Biscuits (7500 Cr)
- ➢ Chapati
- ➢ Pizza

Beverages-Bottled/Packed

- ➢ RTS/Soft drinks
- ➢ Tetra pack drinks

Canned foods

Confectionery

- ➢ Dairy based
- ➢ Sugar/Cocoa based (2500 Cr)

Frozen foods

- ➢ Desserts (800 Cr)
- ➢ Yogurt

Mineral water (1000 Cr)

Pickles/Sauces

Snack Foods

- ➢ Deep fried (500 Cr)
- ➢ Extruded
- ➢ Puffed

Data Courtesy : CMIE Reports

INSTANT FOOD MIXES (Gulab Jamun Mix)

Maida
↓
Sieving
↓
Drying
↓
SMP, Vanaspati, Soda, Acid → Blending
↓
Testing
↓
Fumigation
↓
Packing

- 12 mic PET / 35 mic LLDPE laminated “Stand-up” pouches.
- Shelf-life : 9 months.

CULINARY PASTES
(Multi Purpose Cooking Paste)

Raw Material
↓
Cleaning
↓
Grating / Grinding / Pulping
↓
Shallow Frying
↓
Cooking
↓
Filling into pouches
↓
Master Cartoning

Receipe	**G**
Onion-Grated	: 1000
Tomato Pulp	: 400
Refined Oil	: 300
Garlic Paste	: 125
Ginger Paste	: 125
Salt	: 100
Turmeric powder	: 25
Spices	: 47
Corn Starch	: 5
Citric Acid	: 5

- ☞ pH of Product : 5.10
- ☞ Shelf-life : 6 months in AI Foil Pouches
- ☞ Sodium Benzoate @ 600 ppm used as preservative

- Product when Hot-filled in Retort Pouches and thermally processed does not require preservative.
- Shelf-life : 12 months in Retort Pouches (ITC Product).

CORN FLAKES

Hybrid Yellow Corn
↓
Cleaning
↓
Milling (Bran / Germ Removal – ½ Kernal Bits)
↓
Steeping
↓
Cooking (20 Psig – 2 Hrs – 33 % Moisture)
↓
Cooling
↓
Drying (65^{o}C – 20 % Moisture)
↓
Tempering
↓
Flaking
↓
Gas Oven Toasting (300^{o}C 50 Sec – 3 % Moisture)
↓
Spraying (Vit. / Flavor)
↓
Cooling
↓
Packing

- Corn Grits mashed, cooked in High Shear Extruder – Cooker; Flaked, Toasted and Sugar Coated (Kellogg's Process)

WHEAT FLAKES

Cleaning
↓
Conditioning (21 % moisture)
↓
Steaming (in Bins @ 95^{o}C)
↓
Flattening (Bran Rupturing)
↓
Steeping
↓
Cooking (Rotary Retorts – 20 psig for 90 Min – 45-50 % moisture)
↓
Drying (Through – Flow Drier – 121 to 150^{o}C – 28-30 % moisture)
↓
Holding Drying (Conveyor Drier – 21 % moisture)
↓
Spryaing (Vit)
↓
Heating (82-88^{o}C)
↓
Flaking (10-15 % moisture)
↓
Toasting (Conveyor Oven – 150^{o}C – 3 % moisture)
↓
Cooling
↓
Packing

HEAT-n-SERVE FOODS

(Kesari Bhath / Soji Halwa – RTE Food)

Chiroti Rawa

↓

Vanaspati Roasting

↓

Cooling

↓

Cooking ← (Sugar powder, Water, Vanaspati, Cardamom, Raisins, Color)

↓

Testing

(Sensory / moisture)

↓

Hot filling (Retort Pouch)

↓

Sealing (Vaccum)

↓

Sterilization

(121oC for 20-30 Min – Agitating Retorts)

↓

Cooling

↓

Unit Cartoning

↓

Master Cartoning

Retort Pouch Product is similar to Canned product

Shelf –life : 12 months

Pouch Material

- 25 mic Nylon / 70 mic Cast PP
- 12 mic PET / 9 mic. Al. Foil / 60 mic Cast pp
- 12 mic PET / 15 mic Nylon / 9 mic Al.Foil / 70 mic Cast PP

SELF-HEATING RTE MEALS

- Can-in-Can / Pouch-in-Pouch Concept.
- Flameless Food Heaters are used.
- Pre-coked Meal in Retort Pouches can be heated to Consumption temperature of 65^{o}C in 8-15 min.
- Outer insulated container retains temperature upto 45 min.

Heating System – Exothermic Chemical Reaction

Type	Reactants	Heat Content (Kcal/g)	User
1.	Anhy. Calcium Oxide + H_2O	0.28	"Sake Can" – Japan "Ontro Inc/Hot Can" – USA
2.	Magnesium – Iron Alloy Strip + Water / Saline	3.76	Zesto Therm / Heater Meals Inc / Hot Pack Inc / Alpine Aire Foods, USA
3.	Glycerol + $K_2Cr_2O_7$ / $KMnO_4$ / Na_2O_2	4.15	Tempara Technology, USA Defence Food Res. Lab, Mysore, India

- DFRL Mysore had tested the Type 3 system during the Kargil Conflict on a trial basis.
- Commercial Production of Self-heating Meal packs are yet to begin in India.

FOOD MACHINERY

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CFTRI's Food Processing Division, later renamed as Discipline of Food Engineering and Process Development. The department has computer-assisted section which undertakes prototype design and preparation of project engineering and fabrication drawings for plant and machinery. The section licenses the drawings and design parameters for the equipment it has developed, to the fabricators, on fixed charges. It also takes up design-preparation-vetting assignments for users' plants, on sponsored or collaborative basis.

DEVELOPMENT OF FOOD PROCESSING PLANT AND MACHINERY

Over the years, the department has successfully developed, and in many cases commercialized, food processing plant and machinery particularly needed and affordable by the small scale sector.

Grain milling, cleaning and grading equipment

CFTRI have built prototypes and evaluated performance for paddy separators, rice-bran broken separators, pneumatic grain cleaners/husk separators, vibratory and rotary graders and cleaners for cereal grains, destoners, maize degermer/husker, flour sifters, pulse splitters, dehuskers, mini rice mill, paddy parboiling equipment, and rubber roll paddy shellers. Some of these equipment are already in commercial use.

Evaporators

We have built designs and prototypes for low-cost vacuum evaporators and many types of concentrators such as calendria-type forced circulation evaporators. Some of these designs have been adopted by the food preservation industry for concentration of tamarind pulp extract as well as orange, pineapple and tomato juices, protein hydrolysates and enzymes, pectin solutions, glucose solutions for liquid glucose preparation.

Dehydrators

We have designed and commercialized a number of prototype dryers for diverse applications. Important among these are through-flow dryers, bin-dryers, cabinet-type through-flow dryers, cashew kernel drier, walnut drier, pulse drier, continuous drier for paddy, roto-cone drier, contact plate dehydrator, cross-flow tunnel drier for cardamom, potato slices and garlic, chillies & ready mixes, arecanut drier, cardamom drier and pneumatic flash drier, double drum driers and accelerated freeze-driers.

Machinery for traditional foods

One of our major activities is development of machinery for continuous production of traditional foods. We have fabricated prototypes and evaluated performances of machinery for continuous production of Chapathi (600 numbers per hour), Dosa (400 numbers per hour) and Idli (1200 numbers per hour). These machines are in different stages of commercialization.

Rice bran stabilization equipment

We have developed equipment for thermal (steam-heated) and chemical (by lowering of pH with optimal addition of HCL) stabilization of rice bran as soon as it is milled, to arrest lipase activity. The designs have been released to the industry.

Fruit and vegetable processing equipment

We have developed a citrus juice extractor, fruit slicing/dicing equipment, pulping and juicing machines, washers, crushers, paste-makers, pasteurisers, citrus peel oil extractor and vacuum puffing unit to meet the particular needs of the Indian fruit and vegetable industry which is largely small-scale and medium-scale. The designs for many of these have been released to the industry.

Online retort control system

We have developed this microprocessor-based dedicated control system for the special benefit of India's small and medium size canning (using cans, glass jars and flexible pouches) units and retort manufacturers. The system offers some unique and highly sophisticated hardware and software features to automate the retorting process, with manual loading and unloading of cans.

Other equipment

For certain specific applications, we have designed and fabricated equipment such as walnut huller, walnut washer, spice oil or oleoresin plant, cardamom oil distillation unit, solvent extraction unit, 3000-litre fermenter for yeast manufacture, CNSL bath cashew kernel roaster, continuous roaster for IR radiation of food. Mixers, blenders, conveyors, elevators and wet grinders.

Technical services offered

- Preparation of detailed engineering reports and drawings
- Selection/procurement of equipment for existing as well as new plants
- Participation in erection and commissioning of new plants
- Optimization of process development activities, and production of samples for test-marketing
- Creation of databases to provide information to the industry on physical, thermal, chemical and engineering properties of raw materials, ingredients and finished food products
- Design and fabrication of prototype food processing equipment
- Training of personnel during project implementation

BASIC RESEARCH IN FOOD PROCESS ENGINEERING

- Application of Aqueous Two Phase Extraction (ATPE) technology in extraction of proteins in downstream processing and recovery of bio-molecules
- Application of Supercritical Fluid Extraction technology in extraction and purification of many value-added products from the oil and fat industry
- Application of molecular distillation for extraction of high value products, as in tocopherol enrichment in deodourised distillates, and separation of free fatty acids from DODO
- Application of infrared, microwave and radio frequency radiation in food heating, drying and baking, and IR radiation of food materials
- Fluidised bed and spouted bed roasting.
- Osmotic dehydration and mass transfer of fruit and vegetables
- Membrane separation of crude edible oils for degumming and decolourisation for energy savings and quality improvement
- Cryogenic grinding of spices
- Extrusion cooking of foods
- Engineering properties of foods
- Modelling and simulation of food processes

PROCESS SCALE-UP

Process scale-up has been a major activity of the Food Engineering Department since 1956, and we have scaled up and commercialized laboratory processes that cover.

- Infant food from buffalo's milk
- Integrated utilization of groundnut
- Sterilisation of whole black pepper
- Quick Cooking Rice
- Spray-dried coconut milk
- Downstream processing for natural colours
- Membrane separation and concentration of mango serum
- Development of extruded products

Pilot plant facilities

CFTRI has 100 semi-industrial scale food processing equipment of different designs and capacities. The facilities are open to the Indian industry (on fixed nominal rentals) for identification of machinery for their products and processes, for generation of market samples for their new products and similar purposes.

Some of the major equipments available here are featured below.

- Twin screw extruder
- UF/RO membrane unit
- Molecular distillation unit
- Tortilla press and oven
- Aroma recovery unit
- Supercritical Fluid Extractor
- Rheon encrusting machine
- Aseptic filler
- Dewatering press
- Modular moving bed drier
- Freeze drier
- Double drum drier
- Spray driers
- Flow drier
- Vacuum shelf drier
- Vibro fluidizer drier
- Plate evaporator
- Double effect evaporator
- Single effect tubular evaporator
- Agitated thin film evaporator
- Nozzle centrifuge
- Multipurpose centrifuge

- Suspended basket centrifuge
- Super decanter
- Super centrifuge
- Suspended basket
- Bottom driven basket centrifuge
- Rotary vacuum filler
- Plate & frame press
- Double spiral gravity separator
- Specific gravity separator
- Disintegrator (Rigid hammer mill)
- Comminuting hammer mills
- Continuous through-flow drier
- Forming machines
- Roasters
- Minikek mill-pin mill
- Triple roll mill
- Pulper (Large)
- Fruit crushing mill
- Screw type juice extractor
- Rotary coconut cutter
- Stephan multipurpose mill
- Vegetable slicer/dicer
- Tablet machine
- Flaking machine
- Pellet mill
- Fluidized zone mixer
- Sigma mixer/kneader
- Planetary mixer
- Homogenizer (Piston type)
- Shrink wrapping machine
- Vacuum sealing machine
- Scraped surface evaporator
- Cryogenic size-reduction (grinding) unit
- Mini solvent extractor
- Desolventisor

FOOD TECHNOLOGY – NUTRITION AND HEALTH

IMPACT OF FOOD PROCESSING ON NUTRITIONAL VALUE - AN OVERVIEW

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Foods, today are not only considered as sources of different nutrients which nourish the body but also the main sources of various components which have vast potential in disease prevention and health promotion. To make available good food to the population, food processing is a recognized tool. However, a large number of people often express doubts about the nutritional quality of processed foods and prefer 'fresh' foods for consumption. In this context, an overall picture of the effect of processing on foods and their contents is necessary.

The different types of food processing includes cooking, fermenting, germination, dehusking and milling, parboiling, freezing, malting, roasting, puffing etc. Cooking affects macro and micro nutrients both adversely and beneficially.

Ordinary cooking of cereals, pulses, meat etc causes little loss of proteins, fats and carbohydrates. Cooking in salt water and discarding the water causes some loss in protein. When protein and carbohydrates and heated together, the maillard reaction take place which may make essential amino acids unavailable thus reducing the protein quality. Changes in fats on cooking are seen when the fat is subjected to high temperatures. At high temperatures, the double bonds of unsaturated fatty acids react to form the highly reactive peroxides which may then decompose to form a wide range of substances some of which may be toxic. Overheating/repeated heating results in the accumulation of the products of oxidation.

Carbohydrates do not undergo much change when cooked. Heat processing improves digestibility of starches.

Similarly cooking does not have much effect on the minerals in foods. Losses may occur due to leaching into cooking water. In fact cooking may improve the bioavailability of minerals.

The nutrients most susceptible to losses during heat treatment are the vitamins. The magnitude of loss depends upon the specific vitamin and the medium of cooking. Losses can occur by leaching of water soluble vitamins into the cooking medium and destruction of vitamins by oxidation and presence of alkali.

Significant losses of thiamine occur when rice is washed in excess water and the water discarded. Loss of ascorbic acid is found to be maximum. Oxidation is accelerated by the enzymes present, heat, light, oxygen, alkaline conditions and traces of copper folate and pyridoxin are also destroyed by oxidation. Riboflavin, though stable to cooking is lost on exposure to light. Vitamin A and carotenes are oxidized or undergo isomerization at high temperatures of frying, thus losing their biological activity. Vitamin E is destroyed in frying and is decomposed by light.

Mention must be made of the several benefits of cooking. Cooking improves digestibility of several foods. The bioavailability of may minerals and vitamins improves on cooking. Cooking destroys certain anti nutritional factors like trypsin inhibitors.

Dehusking, milling and polishing

A majority of the staple cereals and millets are subjected to milling to produce flour which is then used for preparation of various products. Grains like paddy are dehusked to obtain rice which may then be polished to obtain the more preferred white grain. Pulses are also dehusked to obtain the dals. Since husk is a poor source of protein, its removal serves to increase the overall protein quality as well as to reduce the tannin content which interferes with iron absorption. During milling, insoluble dietary fiber is lost which may be undesirable from the nutrition point of view.

Parboiling : During this process, the nutrients diffuse into the grain and the starch which is gelatinized forms a protective coating around them, preventing their leaching and subsequent loss.

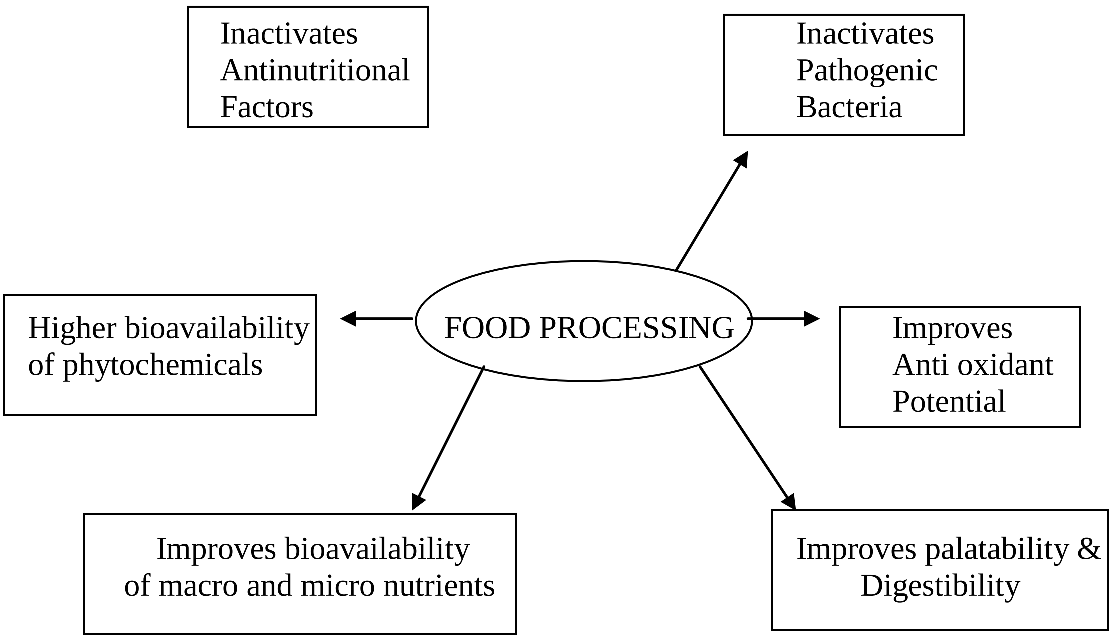
Germination and malting

Germination causes hydrolysis of carbohydrates and proteins and thus reduces cooking time and improves digestibility. Germination also increases the vitamin content of grains especially that of B1, B2 and vitamin C. During germination phytates which bind iron and make it unavailable are also reduced and thus iron bioavailability is improved. Malting further increases digestibility thus making the grain suitable for infants, geriatric population as well as convalescents.

Roasting and puffing : Roasting and puffing improve the flavour, texture and taste of a food and also the digestibility of starch but have a detrimental effect on both thiamine and riboflavin which are considerably reduced.

Fermentation is one method of processing which improve the bioavailability of essential amino acids as well as that of thiamine, riboflavin and niacin. Anti nutritional factors such as phytates and trypsin inhibitors are reduced by fermentation and small amounts of vitamin B12 are produced.

Freezing : Cold storage of fruits and vegetables often causes substantial losses of vitamin C, folic acid and pantothenic acid while moderate amounts of thiamin and riboflavin are also lost. However if vegetables are frozen immediately after hannestemp, the losses of vitamins are prevented to a great extent than if they are stored at ambient temperatures. Of course subsequent thawing results in some loss of the vitamins. Beta carotene is protected from light in frozen foods and therefore losses are lower. Freezing efficiently entraps nutrients and antioxidants and is recommended when considerable time lag is there between harvesting and consumption. Thus the American Frozen Industry Labels these frozen foods as 'healthy'.



Effect of food processing on non nutrient components

Fruits and vegetables contain many non nutrient phyto chemicals besides the known nutrients and these are gaining importance because of the health benefits they give. In many instances processing has been found to affect the bioavailability of both non nutrients and nutrients beneficially. These non nutrient/nutrient phytochemicals include beta carotene, lycopene, anthocyanins, vitamin C, phenolic compounds etc. Most of these compounds exert their health beneficial effects through their antioxidant activity.

Beta-carotene increases as a consequence of processing and cooked carrots, spinach etc have higher anti oxidant potential and protection against oxidative damage as compared to uncooked foods. Similarly lycopene, which has been found to be strongly protective against cancers, is better available from processed rather than raw foods due to transformation of trans isomer to the cis form. Thus intake of processed tomato ketchup would give more lycopene than raw tomatoes.

Anthocyanins which are present in red wine along with Vitamin C help in scavenging singlet oxygen radicals better than those present in fresh grapes. Frozen and canned products have a better nutrient profile than fresh foods.

Oxidised poly phenols in processed products have higher antioxidant potential than non oxidized ohes in raw products. During processing leaching and extraction of phenolic component from peels/seeds occurs which enhances the antioxidant potential of the juice produced. Similarly jamun seeds which are processed by sun drying have high content of phenolic compounds and berry juice concentrate has high anthocyanin extracts.

Thus data shows that processed foods, because of their higher content of antioxidants as compared to raw foods, can effectively counteract adverse effects of oxidative stress and lead to improved immune function. Thus we should change our idea about 'fresh' foods always being better than processed foods. On the whole there are more benefits from processing than losses and maximum use should be made of these.

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PROCESSING OF SOYBEAN FOR DIVERSE USES IN FOOD INDUSTRY

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Soybeans are vital for diverse array of food and industrial products. They provide raw material for cooking oils, salad dressings, several food products, livestock feeds, pharmaceuticals, industrial products, fungicides, antibiotics etc.

Soybean is a complex bean, the term refers to its two principal by products, soybean oil and meal and their special interrelationship throughout the production, processing and marketing.

The present utilisation pattern of soybean in India is that 85 per cent of oil extraction, 10 per cent for seed and only 5 % for food and feed.

The unit operations used in soybean processing are cleaning, grading, drying, dehulling, soaking, blending, heat treatment etc. There should be a good understanding between the physical characteristics (like velocity, temp.) and process for the formation of good quality products.

Soybean is subjected to processing as

- Whole soybean
- Soy meal obtained after oil extraction

The characteristic flavour and astringent tasks will be climate by pre-process techniques like acid / alkali treatment, removal of hypocotyls and developing genetically modified varieties of soybean lacking L1, L2 and L3 lipoxygenase isoenzymes.

Processing of soybean (whole) for use in industry. Three major types of food products can be developed by processing whole soybean.

Whole soybean

Dairy Analogues	**Fermented foods**	**Snack foods**
Soy milk	Temph	Roasted
Soy paneer	Natto	Sprouted
Soy yoghurt	Sauce	Deep prid
Soy ice cream	Miso	Baked items
	Tofu	

Oil is extracted from soybean mainly by solvent extraction method. The major problem in food uses of the present soy problem in food uses of the present soy meal are residual hexane, protein quality and microbial load. CAIE, Bhopal has a package of practices for the production edible grade soybean meal and these practices are based on the application. Hazard Analysis and Critical Control Point (HACCP) system. (residual hexane 50 ppm level). Always a food grade solvent free from all toxic adultants shall be used. Vaccum dissolvent is a better option with adequate temperature control.

Soy protein concentrates (60 % protein) and soy isolates have been developed by further processing of soy flaks / defatted soyflour. A large number of functional properties are attributed to soy protein. They are no standard tasks available for measuring functional properties. These are :

Property	**Food System**
Emulsification	Bread
Emulsion stabilization	Sausages, Soups
Fat absorption promotion, water absorption promotion and retention	Meat, doughnuts and products, meat ___, bread cakes.
Gelation	Coagulated protein, Thickening agents in soups and gravish.
Fibre formation	Simulated meat
Dough formation, adhesion	Baked goods, sausages, meat loaves.
Elasticity	Baked goods, simulated meat.

Extrusion : Extrusion is another concept introduced to mechanical processing of soybean by INT soy. Food extruders performs the functions of mixing, homogenization of ingredients, creating texture, shaping of product, drying and sterilization. During cooking, the protein is denatured, stanch glatimized and flavour and colour of the product were developed. From types of soy products are made by extrusion process.

- Full fat soy flour
- Medium fat soy flour
- Textured soy protein
- Cereal soybean mixtures

The extruded chunks and granules produced by local extruders are sold as Nutrella, Met marker and soybaddi.

National Soybean Research Centre has initiated a programme world initiative for soy in Human Health (WISH H) to promote the use of soy products in developing countries. An India there is a greater scope for improving this technology for production of ready to eat and nutritious snacks.

New openings for soy foods in market : Soy based health Food and Drink launched in New Delhi on 2nd February.

SOLAE in two flavours.

SOY DAY a textural soy protein

STAETA – Low carbohydrate soy milk

Soybean Future and Options

There is a great gap rising in application of food items in low income age groups. This gap must be filled with intensive education to rural folk.

By Overcoming the processing limitations, the resulting dough can be utilized for conventional procedures that may contain 12 g protein / serving.

Dry soyflour + pregelatinized starch along with adequate moisture.

Applications

Baked foods, snack foods, flour made from wheat, potato and rice, crackers, cookies, Pizza crust, breads, buns, tortillas, medical foods – Diabetics, Celiac diseases, pet foods.

Low carbohydrate soy milk

Prosoya foods (India) is promoted by the Canada based prosoya. The company launched its low carbohydrate soy milk under the brand name.

STAETA is Metros and selected cities.

Tie up with Godrej Foods at Bhopal Plant.

The company developed technology for airless cold grinding, which allows extraction of soy milk without beany flavour patented in 40 countries.

Best selling soy beverages in US (silk), Canada (so nice) are made by this process only.

STAETA is available in 200 ml tretrapacks in five varieties, natural, orginal, malt, chacolate and Kesar pista. The company is planning to release 1 lit pack for Rs. 50/-

Soya based health food and drink launched in New Delhi in 23rd February

SOLAE company launched.

Soya Treat Premium in two flavours.

Also launched.

`SOY DAY' a textured soy protein based product in three variants.

Chunks, granules and flakes available in Delhi, Mumbai, Bangalore.

SOYABEAN FUTURE AND OPTIONS

Soybean is so good

Low income	High income
All age groups	All age groups

The most urgent need is to promote the utilisation in needy groups

Application of Food uses

House hold level	Small scale Industrial	Large scale industrial level
------------------------- ------------------------- This gap must be filled with intensive education to rural folk	Encouraging	Expanding

DESIGNER FOODS FOR HEALTH

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The term "Designer Foods" was coined by National Cancer Institute USA in 1989 to describe foods that naturally contain or are enriched with cancer-preventing substances such as phytochemicals. Subsequently, terms like Functional Foods, Nutraceuticals, Novel Foods came into existence. Today, all these terms are being used interchangeably.

There are two main categories of designer foods :

1. **Functional foods** : Foods designed to deliver specific health benefits to the consumer, and …. "whose inherent health benefits go beyond basic nutrition, including the prevention of disease and the promotion of wellness through nutrition… These are similar in appearance to conventional foods and are consumed as part of the usual diet.
2. **Nutraceuticals** : Are products that have been isolated or purified from foods, demonstrated to have a physical benefit or to provide protection against chronic disease. These are generally sold in medicinal forms not usually associated with food.

Given that the health care costs are spiraling and life expectancy is increasing, the popularity of these foods is gaining ground. A study conducted by CII-Mckinsey shows that Healthcare spending would increase from Rs. 86,000 crore in 2001 to Rs. 200,000 crore plus by 2012, of which the private healthcare spending is likely to more than double from Rs. 69,000 cr to Rs. 156,000 cr in 2012.

Some of the plant sources which have been shown to have health benefits are :

Component	**Source**	**Benefits**
Lycopene	Tomatoes	Prevent prostate cancer
Inulin	Whole grains	Improves GI tract health
Flavanols	Chocolate, tea	Circulatory health
Sulforaphane	Broccoli, etc	Boosts antioxidant
Stanols / Sterol esters	Fortified spreads	Reduce risk of heart disease
Isoflavones	Soy	Bone health; menopausal health
Soy protein	Soy	Reduce cholesterol

Food laws are important in ensuring that the consumers get the best products. These laws are well defined in countries like Canada, Japan, USA and EU. There is a lot to be desired in case of Indian Food Laws to ensure that the knowledge created in laboratories is disseminated to the actual consumer.

Some of the major Health concerns in today's scenario are :

- Obesity
- Diabetes (glucose management)
- Bowel / gut health
- Heart / circulatory health
- Sodium levels
- Nutrition / diet

Some of the global trends for the future development of functional foods are listed below :

1. Nutrient horsepower

Positive Eating *Au Naturel* : Whether the objective is to maintain health or reduce risk, shoppers prefer naturally nutritious foods to fortified foods.

65 % consumers buy citrus fruits for Vitamin C
36 % consumers buy apples for fibre content
48 % consumers buy oatmeal to reduce cholesterol

OmegaTech's Gold Circle Farms brands have created eggs that deliver higher Vitamin E and omega 3 content.

2. The new youth market

With french fries and potato chips accounting for 25 % of kids and 30 % of teens vegetable intake, the trend is to produce highly fortified high-fiber drinks and snacks.

- Balance Bar's Kids Balance with 25 % of 24 nutrients, soy and fiber for growing kids.

3. Upgrading of fun and favourite food

Earlier, food manufacturers felt that there was a disconnect between healthy and fun foods. However, 65 % people would eat their favourite food enriched with soy protein to improve health.

In US, candies fortified with vitamins A, C & E and calcium are gaining ground. Ex : Brach's Hi-Candy, Odwalla's Fruity C monsters.

4. Tailor made foods

Customization for specific segment is the key.

- MenopausativeTM (Natural Vitality, California), nutritional supplement beverage contains 100 + mg of soy isoflavones, plus herbs and nutrients.

5. The Rx/OTC interface

There is an opportunity to develop natural, non-threatening alternative food and beverage option to Rx/OTC products that offer symptom relief, risk factor reduction or aid in disease management.

- Digestive upsets
- Cholesterol reduction
- Joint pains / Bone strength

Several new Euopean probiotic strains have been shown to destroy H. pylori, the organism responsible for peptic ulcers.

FOOD TECHNOLOGY – SCOPE OF INGREDIENTS IN PROCESSING

APPLICATION OF ENZYMES IN FOOD INDUSTRY

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- Enzymes may be used in industry as components of living cells (or) after isolation, in free or immobilized forms. All of these may be referred to as bio-catalysts.
- The first enzyme produced industrially was fungal amylase takadiastase in US in 1964.
- By 1985, 2500 enzymes were known, 250 were marketable.

The prospects of enzyme application

(i) High yield obtained by genetic manipulation.

(ii) Optimization of fermentation conditions) i.e., low cost nutrients, optimal utilization of components in nutrient solution) and introduction of fed batch fermentations.

(iii) New cell breaking methods for release of enzymes from cells.

(iv) Modern purification processes such as counter current extraction ion-exchange chromatography, affinity chromatography and precipition techniques.

(v) Development of process for immobilization of enzymes and for their recycling.

(vi) Continuous enzyme production in special reactors

Application of enzymes

- In food industry, the activity of certain enzymes may be determined before and after pasteurization and sterilization processes to check whether these have been properly carried out. For example: alkaline phosphatase and invertase present in milk are inactivated during sterilization and pasteurization, so the activities of these enzymes at the end of the process give an indication of sterilization effectiveness.
- The degree of bacterial contamination of food stuffs can be estimated by the assay of microbial enzymes not normally present in food. For example, milk should contain only small amounts of reductases, but bacteria produce large amounts.
- Enzyme assay used to determine stored plant products are suitable for use as food stuff. For example: a-amylase should be present in relatively low amounts in stored wheat seeds. However, if sprouting (i.e., germination of the stored crop) takes place, it indicated greatly increased production of a-amylase and some proteolytic enzymes. These cause

breakdown of the reserve starch and proteins. Hence, the flour made out of the sprouted wheat is not suitable for baking purpose.

- Freshness of meat may be determined by the use of monoamino ioxidase to detect amines formed during degradation. Also enzyme immuno assay methods (EIA) – ELISA (enzyme linked immunosorbent assay) and EMIT (enzyme multiplied immunoassay technique) are used to detect food adulteration.
- The traditional use of yeasts in the baking and brewing industries arose because they contain enzymes for alcoholic fermentation.
- In brewing, the main starting material is malt, produced by allowing barley seed to germinate in moist conditions.
- The reserve starch is broken down by the amylase present to give, among other products glucose and maltose. The wort is further flavoured with hops, and then yeast is added to produce ethanol, by alcoholic fermentation of glucose and maltose.
- Bacterial a-amylase which is even more heat stable than wheat a-amylase is used in brewing industry.
- For production of glucose from starch on an industri9al scale, starch is first solubilized and partly degraded by bacterial a-amylase and then treated with fungal amylo glucosidase. These can cleave glycosidic bond in starch to give good yields of liquid glucose.
- Invert sugar – a mixture of glucose and fructose, is produced from sucrose by the action of yeast, β-fructofuranosidase, better known as invertase.
- The clarification of wines, and fruit juices is usually achieved by treatment with fungal pectinases.
- Papain is used as meat tenderizer, some South American natives traditionally wrap the meat in leaves of papaya, the fruit from which papain is extracted.

Application of various food enzymes

Enzyme	Application
Alpha-amylase	Starch syrups Ethanol Fermentation Animal feed
Beta-amylase	Brewing Maltose syrup
Cellulase	Animal feed
Beta-Glucanase	Brewing
Beta-Glucosidase	Isoflavones
Dextranase	Hydrolyzes dextran
Dextrinase	Cleaves dextrins and release glucose
Alpha-Galactosidase	Beet industry, release more sucrose
Glucoamylase	Dextrose syrups High fructose syrups
Hemicellulase/pentosanase/Xylanase	Baking industry Fruit juice industry
Invertase	Invert sugar (HFCS)
Lactase	Removes lactose from milk
Naringinase	Debitter citrus juices
Pectinase	Fruit processing (Jams,Jellies)
Proteases	Brewing Baking Protein hydrolysates Distilled spirits
Acid protease	Baking
Bromelain	Protein hydrolysates Digestive syrups
Pepsin	Cheese production
Chymosin	Cheese production
Amino-peptidase	Food and animal feed
Subtilisin	Food and animal feed
Lipases	Dairy Industry
Esterase	Dairy Industry
Lysozyme	Dairy (Antibacterial)
Glucose isomerase	HFCS
Catalase	Desugaring of eggs
Peroxidase	Marker for processed foods such as canned and dehydrated foods
Acetolactate decarbosylase	Brewing

ADDITIVES – THEIR ROLE IN FOOD PROCESING

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Food additive may be defined as non nutritive substances added intentionally to food generally, in small quantities to improve its appearance, flavour, texture or storage properties.

The USA Federal Food Drug and Cosmatic Act approved on 25 June 1936 a food additive is a substance or a mixture of substances, other than a basic food stuff, which is present in food as a result of any aspect of production, processing, storage or packaging. The term does not include chance contamination.

Broad classification of intentional Food additives (Benden, 1988).

1. Preservatives
2. Anti oxidants
3. Sequestrates
4. Surface active agents
5. Stabilizers and thickners
6. Bleaching and maturing agents and starch modifiers
7. Buffers, acids and alkalies
8. Food colours
9. Non-nutritive and special dietary sweeteners
10. Nutrient supplements
11. Flavouring agents
12. Miscellaneous

Preservatives : These include chemical preservatives against bacteria, yeasts and moulds.

Examples :

Sodium benzoate - Used in soft drinks and acidic foods.

Sodium and calcium propinates – Used in breads and cakes as a mould inhibitor.

Sorbic acid – Used in cheese

Chlorine compounds – usedin Fruits and vegetables as a germicidal wash

Ethylene oxide and Ethyl formate used in spices, nuts and dried fruits as a fumigant to control microorganisms.

Sulphurdioxide used in fruits and vegetables, to control enzymatic browning.

Antioxidants : These include the compounds used to prevent oxidation of fats in many processed foods such as potato chips, breakfast cereals, salted nuts, biscuits etc. and helps in preventing rancidity.

Ex : Butylated hydroxyl anisole (BHA)

Butylated hydroxyl tolune (BH7)

Propyl gallate

Nordihydro guiaretic acid (NDGA)

Tocopherols

Ascorbic acid

Sequestrants : They react with trace elements such as iron and copper present in foods and remove them from solution. The trace elements are active catalysts of oxidation and discolouration of food products.

Ex : Ethylene diamine tetra acetic acid (EDTA)

Polyphosphates

Citric acid

Surface – acting agents : These include emulsifiers used to sterilize mixtures of oil in water and water in oil, gas in liquid mixtures, and gas in solid mixtures. They act as emulsifing agents, wetting agents, solubilizers, suspending agents and complex agents.

Ex : Natural Emulsifier – Lecithin

Synthetic emulsifiers - Mono and diglycerides and their derivatives, bile acids.

Bleaching and maturing agents and starch modifiers

Freshly milled flour has a yellowish tint and suboptimum functional flour has a yellowish tint and suboptimum functional baking properties. Both the colour and baking properties improve slowly during storage. These improvements can be obtained more rapidly and with better control through the use of oxidizing agents.

Eg : Benzyl peroxide, bleaches yellow colour

Oxides of N2, chlorine dioxide and other chlorine compounds used to bleach colour and mature the flour

Hydrogen peroxide used to whiten the colour of milk in cheese manufacture and bleach

Bromate and iodate used as oxidizying agents, to condition bread dough for optimum baking performance.

Starch modifiers : Sodium hypochloride which oxidize starches to a higher degree of water solubility.

Flavouring agents and flavour enhancers : These includes both natural and synthetic flavours.

Natural flavouring substances : Spices, herbs, essential oil and plant extracts.

Synthetic flavouring substances : Benzoldehyde has Cherry flavour.

Ethyl butyrate has Pine apple flavour.

Methyl authranilate has Grape flavour.

Methyl salicylate has Winter green flavour.

Currently there are more than 1200 different flavoring materials used in foods, due to ever increasing variety of different loads including foods of international character. They are also used to replenish flavours partially or completely lost by various modern processing methods involving heating, concentrating, drying and other food handling practices.

Flavour enhancers : These compounds do not have flavour but intensify the flavour of other compounds present in foods.

Ex : Monosodium glutamate
5 - nucleotides

Non-nutritive dietary sweeteners

Eg : Saccharin – used in soft drinks for diabetic subjects. Daily intake should not exceed 1 g by an adult as it will cause bladder tumours.

Nutrient supplements : Vitamins and minerals are added as supplements and enrichment mixtures to number of products.

Vitamin D – Milk
B – Vitamins, iron and calcium – Cereal products

Iodine – Salt

Vitamin A – Margarine, Cheese, dietary infant formulas.

Vitamin C – Fruit slices and fruit flavoured deserts.

Food colours

Natural colours - Annatto, Caramel, Carotene, Saffron

Synthetic colours - 1) Coaltar dyes – Used in carbonated, beverages, candies, gelatin desserts and bakery goods

2) Inorganic materials : Iron oxide – gives redness

Titanium oxide – Intensify whiteness.

Extracts of synthetic equivalents

B-carotene
B-apo-8-carotenal
Methyl ester of B-apo-8-carotenoic acid
Ethyl ester of B-apo-8-carotenic acid
Cantharathin
Chlorophylls
Riboflavin
Caramel
Annatto
Ratanjot
Saffron
Curcumin (turmeric)

Stabilizers and thickners : These stabilize and the clean foods by combining with water to add viscosity and to form gels.

Eg : Gums; gelatin, starches, dextrins and protein derivatives

Used in gravies; pie filings, cake toppings, chocolate milk drinks; jellies, puddings and salad dressings.

They contain : gum arabic, carbosey methyl, cellulose, pectin, amylose, hydrolysed vegetable proteins and gelatin.

Miscellaneous

Solvents used in manufactured foods and drinks

Dichloromethane and Trichloroethylene used in decaffeination of coffee and tea

Fat substitutes used in food ingredients / novel foods.

Safety of food additives

- To establish absolute proof of the non-toxicity of a specified use of food additives for all human beings under all conditions is impossible. Critically designed tests of physiological, pharmacological and biochemical behaviours of a additive can provide a reasonable basis for evaluating the safety use.
- Presence of harmful impurities in additives can be excluded by establishing specifications of purity.
- The minimum limit of adding food additive to be established to get the desired effect.
- Legal control over the use of food additives to be established by establishing permitted list.
- Food label information to be provided.
- Trained food inspectors, food control laboratories and reliable analytical methods are very important.

Additives to be used with Caution

Additive	**Use**	**Possible adverse effects**
Coal tar dyes	Colourant in vegetable and fruit products, soft drinks, candy, desserts, pastry, sausage, baked food, ice cream, hot dogs, hamburgers, sweetmeats, snacks, confectionery, alcoholic and other beverages.	Allergic reactions, cancer and pathological lesions in vital organs.
Bytylated hydroxytoluene (BHT)	Antioxidant in cereals, chewing gum, potato chips, edible oils etc.	Cancer; allergic reactions, stored in body fat
Butylated hydroxyanisole (BHA)	-Do-	Appears to be safer than BHT but needs more testing
Caffeine	Stimulant in soft drinks	Insomnia and other adverse effects at high levels of intake. Not recommendd for children and pregnant mothers.
Saccharin	Non-calorie, sweetner in food products, also as adulterant	Bladder cancer reported in animals. Not recommended for normal people (not suffering from diabete, obesity)
Sodium nitrite and nitrate	Preservative to prevent growth of bacillus, clostridium, botulinum	Formation of small amounts of cancer producing nitrosamincs

Additive	Use	Possible adverse effects
	and colourant for bacon, ham, meat smoked fish, corned beef	
Artificial flavourings	In soft drinks, breakfast cereals, baked goods, vegetable and fruit product ice creams custards, desserts alcoholic beverages	Hyperactivity in some children; not adequately tested for safety
Monosodium glutamate	Flavour enhancer for soup, poultry, meat preparations, sauces, stews and cheese	Damages brain cells in infant mice (so not recommended for children), headache, tightness of head, neck and arms in sensitive adults (Chinese Restaurant Syndrome)
Sulphur dioxide and bisulphites	Preservative and bleach for sliced fruit, wine, grape juice, dried potatoes, dried fruit, vegetable and fruit products etc	Destroys vitamin B1, but otherwise safe at prescribed levels
Phosphoric acid and phosphates	Acidifier, chelatin agent, buffer, emulsifier, nutrient, discoloration inhibitor used in baked goods, cheese, cured meat, soft drinks, dried potatoes	Dietary imbalance that may cause bone thinning (osteoporosis) on prolonged use
Talc and kaolin	Making dry powdery foods free-flowing and as dusting agent for rice, confectionery, chewing gum	Absorbed and stored in vital organs, cancer if asbestos is present

Substances prohibited as additives in foods

- Brominated vegetabvle oil (BVO)
- Calamus and its derivatives
- Chlorofluorocarbon properllants
- Cobalt salts and their derivatives
- Coumarin and dihydrocoumarin
- Cyclamate and its derivatives
- Diethylpyrocarbonate (DEPC) dulcin
- Monochloroacetic acid
- Nordihydroguaiaretic acid (NDGA)
- Safrole
- Thiourea
- Colourants
- Acid Magenta II
- Blue VRS
- Brilliant Black
- Red FB
- Red 6B

Additives-as macromolecule replacers in food formulation

A few decades ago “light” foods were known, but now increasing numbers of these products are found on grocers’ shelves and in freezer cases as choices for consumers searching for alternatives to satisfy their desires, yet maintain their health. Formulation of these foods of choice have been made possible by use of food additives. Manufacturers are scrambling to develop new technologies and expand the uses of low calorie ingredients, and consumers are feeling increasingly comfortable with the concepts of fat and sugar.

New materials both natural and synthetic-have been introduced as replacement ingredients for producing low-calorie and reduced fat products. Some materials are traditional macromolecules with new uses, but others are synthesized materials that have been introduced to replace sugar and / or fat components of food products. The broad categories of macromolecular replacements, some of which are also considered as bulking agents, include carbohydrate based, protein based, lipid based, and mixed blend replacers. The carbohydrate-based replacements can be classified as

1. Glucose polymers and starch derivatives (polydextrose, maltodextrins, dextrins and modified starches) or modified sugars (is malt, insulin and perhaps even sucrose esters, although they usually are regarded as emulsifiers).
2. Mixed hydrocolloids, including fibers and gums.

Proteins that are used for fat replacement include micro- particulated egg albumens, caseins, whey albumins, and whey globulins. The lipids are either emulsifiers or fat analogs that have been modified or synthesized such that they are no longer metabolized completely. The functional attributes that must be provided by the sweetener system to be used as a sugar replacer have been outlined in relation to both sensory and processing requirements. Solubility (usually in water), retention a (release) of water, reduction of water activity, retardation of bacterial growth, air incorporation and coagulation temperatures in bakery products, ability to depress freezing point in frozen products and control of crystal formation in confectionery products are critical functions, not withstanding providing sweetness, which is performed by the sugars. The volume lost when sugar is removed must be replaced, generally by compounds that bind water through molecular attraction, capillary action, or slowing water molecule movement through the matrix. The combination of water with binding agents provides the necessary bulk lost with the sugar.

In order to create sensory textural perceptions of high fat levels, factors suggested for macromolecule substitutes include.

1. The size of the particles i.e. small, uniform micro particles from 0.1 to 3 μm that promote textural creaminess in dairy products, frozen desserts and salad dressings and particles in the size range of fat crystals (20 to 30 μm) that produce deformable gels with a short texture, and
2. Water binding or water structuring to promote the perception of moistness associated with high fat in bakery products.

SALATRIM, a family of low calorie fats, containing mixture of long chain saturated fatty acids: has physical properties of fats, but only about half the calories of an ordinary edible oil and is a safe and versatile fat substitute. CAPRENIN, a randomized triglyceride containing caprylin, (C 8:0), capric (C 10:0) and behenic (C22:0) acids has functional and organoleptic properties similar to cocoa butter and thus can be used as a confectionary fat. It provides fewer usable fat calories than ordinary fats because behenic acid is not completely absorbed.

Bio – Food additives – New generation additives for food

There has always been an increased consumer response towards natural ingredients in food systems, which are used for the manufacture of clean label products, containing no artificial additives. This caused a renewed interest among food scientists which directed their attention towards compounds of biological organic In view of this, focus is now being drawn towards utilization of biotechnological applications such as microbial genetics, fermentations, enzymatic processes etc.

Biocolours

Consumer awareness and concern for healthful and perfectly balanced food has resulted in increasing interest for food colourants of natural origin. Natural colours are generally extracted from fruits, vegetables, seeds, roots and micro organisms and they are often called ‘biocolours’ due to their biological origin. Algae, bacteria and plants are the three important sources of biocolours. The commonly available commercial natural colourants of plant origin are carotenoids (extracted from citrus peel/pulp), oleoresin (extracted from Bixa orellana), carrot extracts, chlorophylls and heterocyclic pigments like flavones and anthocyanins-oenocyanin and betanin. Common plants, whose extracts are reported to have some role as natural food colourants are curcuma root, citrus oils, gardenia, saffron, carrot, paprika, hibiscus, beetroot, purple corn, sandalwood and spinach. Some natural colourants include β-carotene, (butter, cheese, margarine, oils, fats, fillings, instant soup powders) canthaxanthine (salad dressings, meat products, meat substitutes, products based on soy or other cereal proteins, SCP or fish proteins, shrimps and lobsters). Increasing preference for natural food colours has led to the need for finding alternative biotechnological means of augmenting production of natural pigments.

Saffron (*Crocus sativus*) which is an important food additive both for its colour and aroma is restricted to certain geographical locations in the world. Mereover, the plant produces only one or two trifed stigmas per year, thereby rendering it difficult to produce in very large amounts. To obtain 1 kg of dry stigma, one needs to harvest 1,50,000 flowers of saffron. Biotechnology has made the production of stigma in culture possible.

Production of root-derived compounds in controlled environment has been made possible using hairy root culture techonology, an important biotechnological method.

Phycocyanin which is a blue pigment has been developed by processing of cyanobacterial biomass such as spirulina. Safety analysis of phycocyanin finds its use as colourant in icecreams, toffees, beverages and in cosmetics.

Bio flavours: Microbiological processes are considered to be a better option for the production of flavours. The production of flavours may involve mainly two routes.

1. Biosynthesis of a specific compound by metabolizing cells
2. Biotransformation or bioconversion which involve modification of chemical substrate by microbial cells.

The major microbial flavour sources include bacteria, yeasts and filamentous fungi. Some of the most common flavour compounds produced from mircrobial sources are terpenes, alkylpyrazines, carbonyls, aldehydes, lactones, etc.

Plant tissue culture (PTC) technique has been exploited for the production of food flavours from straw berry plant, apple, grape, pineapple and raspberry. Vanillin flavours have also been produced by culturing callus cells derived from vegetative vanilla tissue. However, because of some inherent difficulties like slow growth rate, low yield as compared to microbial sources, use of PTC as an economically viable source for production of flavours in food industry is questionable.

The development of novel and cheap production processes such as solid state fermentation may help to overcome some of the current limitations of microbial flavour production and also widen the spectrum of bio production of such compounds.

Biosurfactants

A wide variety of microorganisms have been identified that are capable of producing numerous kinds of extracellular and cell associated surface active agents when grown on specific substrates in submerged fermentation. These microbial surface active agents or biosurfactants are claimed to have a broad spectrum and in some cases, specific functionality, rapid biodegradability i.e., environmental acceptability and possible low toxicity. Some of the most thoroughly characterized microbial surface active agents are the glycolipids containing hydroxy fatty acids covalently bonded to carbohydrate trehalose, rhamnose and Sophorose.

There is a need for intensive investigation on selection of microbes that can utilize cheaper feed stocks and produce large quantum of broad spectrum surfactants and on developing technology for product recovery in a high state of purity. Natural antioxidants have been extracted from plants of labiatae family out of which rosemary and sage were found to be most effective in stabilizing soybean and vegetable oils.

Thaumatin – a powerful natural sweetening agent

A natural protein extracted from the berry of a West African plant called the Katemfe (Thaumatoccus daniellii) plant, thaumatin is listed in the Guinness Book of World Records as the sweetest substance known, being 2000-2,500 times sweeter than an 8-10% solution of sucrose. Thaumatin has four primary functions which are flavour enhancement, masking bitterness, providing better mouthfeel and providing synergy with sweeteners and other ingredients. Thaumatin, as a protein is completely digested by man and animals, which accounts for its acceptance by regulatory authorities throughout the world as a safe, natural substance; and is listed in the Generally Regarded as Safe (GRAS) list. Hence, thaumatin being a natural product, may find use in natural label products. With increased consumer response towards natural ingredients in food systems, which are required for manufacture of 'clearl label products' containing no artificial additives, more and more newer biotechnological processes will have to be employed for the production of natural food additives which are the new generation additives for foods.

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FOOD TECHNOLOGY – QUALITY ASPECTS

INGREDIENT INTERACTIONS IN FOOD PROCESSING - EFFECT ON FOOD QUALITY

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Fondness for good food has been a characteristic of mankind through the ages. For centuries, there has been a keen interest in developing desirable flavour and appetizing colours in foods for they undoubtedly add to the enjoyment of eating. Thermal treatment of foods is broadly effective and relatively inexpensive method of rendering foods safe from human pathogens and determination of spoilage microorganisms and undesirable enzymatic reactions. However, heat treatments are also associated with a number of adverse effects on colour, flavour, appearance and wholesomeness of the products. These effects result from various food ingredient interactions that occur during different processing such as baking, roasting, toasting, concentration & dehydration of foods. The interactions include carbohydrate – protein, protein-protein, protein-lipid, protein-alkali, water-protein, water – lipid, carbohydrate – lipid, flavor- nutrient etc. These interactions which occur not only during heat processing but also as a result of prolonged storage of food stuff is of major importance in obtaining food with a pleasant flavour.

Proteins – Carbohydrate / Lipid interactions

Browning reactions of amino acids and proteins with carbohydrates, oxidized lipids and oxidized phenols cause deterioration of food during storage and processing. Specifically, reactions of amines, amino acids, peptides and proteins with reducing sugar and vitamin C (nonenzymatic browning, often called Maillard reactions) and quinones (enzymatic browning) cause deterioration of food during storage and commercial or domestic processing.

The following outlines of categories and examples gives an indication of the complex dynamics of browning in food .

1. Heat catalysed protein / amino acid – carbohydrate reactions

Ex : Wheat gluten plus glucose (bread crust)
Lactablumin plus lactose (stored milk powder)
Free amino acid plus glucose (Fried potatoes)

2. Oxidized lipid reactions :

Oxidized lipid derivatives affect flavour adversely but also interact with proteins.

Ex : Peroxidized methyl linoleate induces significant losses of lysine, methionine, tryptophan and cystein in whey proteins.

3. Heterocyclic amine forsation

Ex : Heat catalysed reactions of amino acid, glucose and creatinine to form polycyclic amines in cooked meat and fish.

4. Oxidized polyphenol (Quinone) reactions : The enzyme polyphenol oxidase (PPO) catalyses two reactions – hydroxylation of tyrosine to O-dihydroxyphenyl alanine (DOPA) and oxidation of DOPA and other O-phenols to O-quinones. The quinones can then either undergo further oxidation to brown melanin pigments or participate in addition–polymerization reactions with protein functional groups to form cross linked polymers.

Beneficial Maillard Products

Antimutagens : Antimutagens can be classified into a) desmutagens which inactivate mutagens by chemical or enzymatic modification & b) Biomutagens which suppress the mutagenesis after the DNA has already been modified by mutagen. Maillard reaction products act as antimutagens in both ways. Other mechanisms that have been proposed to explain the antimutagenicity of Maillard Products include a) scavenger of free radicals b) Inhibition of enzyme activity of S9 microbial mixture needed to activate mutagens c) Degradation of nitrite and prevention of mutagenic nitrosamine formation. Flavours present in carrot and potato also inhibit the mutagenicity by directly reducing the hepatic microsomal activation.

Antioxidants : Controlled browning of foods often leads to the formation of natural antioxidants. Scavenging of active oxygen species by Maillard reaction products is an important mechanism of antioxidative effects.

Antibiotics : Maillard reaction products are shown to inhibit the growth of bacteria such as Lactobacillus, Salmonella and Streptococus faecalis strains i.e. both pathogenic and spoilage organisms found in foods. Potential targets for the action of antibacterial antimicrobial Maillard compounds include a) Cellular membranes b) Genetic material and c) Bacterial enzymes. First, the Maillard products influence the solubility of iron, second because iron in bacterial cells is a cofactor in metabolism of oxygen, these products also inhibit oxygen uptake. Third, Maillard products also inhibit the uptake of glucose and serine by the bacteria. Finally Maillard products are also reported to inhibit digestive enzymes.

Nutrition and Safety : Rat feeding studies of the modified protein revealed a reduction in PER, nitrogen digestibility and other indices of protein quality. Restricting free access to oxygen during food packaging and maintain low water activity will protect the protein in a mixed food from damage due to reactions with peroxidized lipid. Physiological and pharmacological effects of Maillard products which may adversely affect protein, mineral and vitamin nutrition include a) inhibition of process such as growth, protein & carbohydrate, digestion, amino acid absorption and activity of panomatic and intestinal enzymes b) Induction of cellular changes in the kidney, liver and stomach cecum c) Adverse effects on mineral metabolism (Ca, Mg, Cu and Zn).

Mutagenic Maillard products

Mutagenic and carcinogenic products in cooked protein rich foods are formed by several mechanisms. Of special interest is the formation of heterocyclic amines in heat processed fish and meats. These compounds are the most potent mutagens known and they induce a variety of tumours in rodents and are extremely potent hepatocarcinogens when tested in primates. Since all mutagens tested so far in animal studies have been found to be carcinogenic, it is desirable, although difficult, to control mutagens in food, the higher temperature recommended to destroy pathogens in meat may lead to the formation of greater amounts of heterocyclic amines possible approaches to minimize heterocyclic amine / mutagen / carcinogen formation during cooking include type of cooking procedure, cooking temperature and the role of added food ingredients.

Prevention

Sulfhydryl compounds : Sulfur containing amino acids and glutamine play key roles in the biotransformation of toxic compounds by actively participating in their detoxification. These antioxidant and antitoxic effects are due to a multiplicity of mechanisms including their ability to act as a) reducing agent b) scavenger of reactive oxygen c) destroyers of fatty acid peroxide d) Precursor for intracellular reduced glutathione.

Acetylation of Amino groups : Modification of amino groups prevent them from participation in browning reactions.

Acrylamide formation

Potato chips, French fries and many other foods fried or baked are reported to be containing the chemical acrylamide formed by the reaction between protein and carbohydrate. Acrylamide is implicated in carcinogenesis and is reported to be present in significant concentration in many every day foods. The studies on laboratory animals revealed that it causes neurological damage, genetic mutation and impair fertility.

Resistant Starch : While starch was long thought to be completely digested, it is now recognized that there is a portion (resistant starch) which resists digestion, passes into the lower intestine, and is fermented there. Resistant starch has been defined as "the sum of starch and products of starch degradation not absorbed in the small intestine of healthy individuals". Three types of resistant starch have been identified.

1. **RS 1 : Physically trapped starch** : The starch granules are physically trapped within a food matrix so that digestive enzymes are prevented or delayed from having access to them.

   Ex : Whole or partly ground grains. The amount of type 1 resistant starch will be affected by food processing.

2. **RS 2** – **Resistant starch granules** : Certain raw starch granules such as potato and green banana are resistant to attack by α-amylase due to crystalline nature of the starch.

3. **RS 3 – Retrograded starch** : The amylose and amylopectin components of starch undergo the process of retrogradation in a time dependent process after starch has been gelatinized / cooked. Amylose can be retrograded to a form that resists dispersion in water and digestion with α-amylase.

Starch that is not digested in the small intestine is lost to the large intestine, where it may undergo fermentation by the microflora. The resistant starch that reaches the more distal part of the small intestine may find application in improving the carbohydrate tolerance of diabetics. Carbohydrate fermentation in the large intestine may be a major protective factor against the development of colon cancer. There is currently great interest in resistant starch because of its potential use as a food ingredient to increase the dietary fibre content of food and also because it may be possible to manipulate the amount of resistant starch in food products through processing conditions.

Protein – Protein interactions : Heat and alkali treatments of foods, widely used in food processing, result in the formation of dehydro and cross linked amino acids such as dehydroalanine, B-aminoalanine, lysinoalanine, ornithoalanine, lanthionine and are frequently accomapined by concurrent racemization of L-amino acid isomers to D-analogues. Processing conditions that favour these transformations include high pH, temperature and exposure time. The presence of lysinoalanine residues along a protein chain decreases digestibility and nutritional quality. Factors that minimize lysinoalanine formation include the presence of SH-containing amino-acids, sodium sulfite, ammonia, ascorbic acid etc. and acylation of epsilon-NH2 groups of lysine.

Protein containing foods are commonly treated with alkali for preparing protein concentrates and isolates for dietary uses. Similarly alkali treatments are used in recovering proteins from cereal grains and oil seed by products. Alkali treatments are also used to induce fiber-forming properties for use in textured soybean foods. It is now generally recognized that alkali treatment can damage nutritional quality of proteins and possible cause for this include destruction of the essential amino-acids lysine and threonine and of the semi essential amino acid cystine, reduced digestibility due to formation of cross linked and D-amino acids, loss of phosphorus form phosphoproteins such as casein and adverse effects on mineral nutrition due to chelation of trace elements.

Flavour – ingredients interaction

Flavours are made up of complex composition of natural and synthetic ingredients. A large number of volatile aroma compounds have been identified in foods and beverages, but not all these actually contribute to perceived flavour. During storage, reactions such as oxidation, hydrolysis and vaporization can occur so that desired attributes may be lost and development of off flavours can occur.

a) **Lipid - flavour interactions** : Lipids have their own flavour and they act as precursor for flavour development. Lipids can stabilize flavour by interfering with solubility of reactants and lower the vapour pressure thus increasing their thresholds. Lipids can effectively alter the flavour balance of a product as a consequence of their improper addition. It is difficult to make reduced fat foods with good flavour because the flavour contributed by fat is less and the ingredients off flavour may be more prominent. Since flvours must be used differently in reduced fat systems, a variety of approaches and technologies must be tried.

b) **Carbohydrate – flavour interactions** : Like lipids, carbohydrates can also complex with flavour and reduce its vapour pressure. Hydrocolloids tend to affect rate of flavour release by virtue of their viscosity, which hinders transport to the vapour phase. Starches lose substantial part of their flavour – binding capabilities after partial hydrolysis to dextrins. An increase in gelling agent content will require an increase in flavour.

c) **Protein flavour interactions**: Proteins have little flavour of their own. But they influence flavour perception via adsorption of flavour compounds. Denaturation of protein can increase absorption of flavour probably by greater exposure of the protein. Protein containing food products that are processed at high temperatures tend to bind more flavour and allow less to be available.

In conclusion, an important objective of research in food science is to fully understand the underlying chemistry and the resulting nutritional and toxicological consequences of ingredient interactions to optimize processing parameters that minimize adverse effects and maximize beneficial ones.

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NATURAL COLOURS IN FOOD PROCESSING

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The trend towards natural ingredients in food stuffs is continuing and this is evidenced by consumer acceptance of 'natural' foods and the various International Regulations which completely or selectively ban artificial colours from food. Currently, the degree of safety testing required of a synthetic compound designed for food use is prohibitively expensive and the less stringent testing designated for natural compounds has obvious attractions.

Natural colourants produced for use in analogous way to the coal-tar dyes are crude extracts of pigments. The fruits and vegetable pigments are mainly classified into three groups : chlorophylls, carotenoids and flavonoids.

Chlorophylls

Chlorophyll forms an essential part of and contributes massively to the environment. Physically it is held between layers of lipid and protein in the leaf chloroplast. The layers are disc-shaped particles of approximate diameter 0.1 mm. Dry chloroplasts contain approximately 10 % chlorophyll and 60 % protein. The chlorophyll molecule consists of two parts, the magnesium-chelated tetrapyrrole which is associated with the protein, and the fat-soluble phytol 'tail' associated with the lipid layer. Chlorophyll in plant tissue is protected from acidic plant saps by its linkage with the protein, but this is easily broken during processing and storage.

Chlorophylls a and b are the chief forms of the pigment existing in higher plants and algae. Under acidic conditions and at higher temperatures, the magnesium atom is replaced by hydrogen to form pheophytin. The green chlorophyll pigments are slightly water soluble, and in an acid medium are converted to the olive-green pheophytin regarded as undesirable by people of many nationalities. In an alkaline solution chlorophyll is a bright green.

Natural magnesium chlorophyll extracts of suitable purity area not available for food use, but several patents are listed concerning chlorophyll pigments. The chlorophyll colours used as food colourants have been saponified to produce chlorophyllins which may contain sodium, potassium or copper. This process results in increased light stability. Copper chlorophyll is water-soluble, but solutions precipitate out at low pH. They are most suitable for products with a pH greater than 7.0, when they are stable to temperatures upto 120^{o}C. This can be one of the more stable natural colour additives and its performance has been described as satisfactory in a wide range of products. Applications include ice cream, sweets, bakery products, jams and jellies.

Carotenoids

Carotenoids occur almost universally in nature, where they contribute to the colour of many yellow, red or orange organisms. They are synthesized by bacteria, fungi and higher plants and are present in food such as carrots, citrus fruits and tomatoes. The presence of carotenoids in many plants is marked by chlorophylls, and they may only become apparent when the green fate in autumn or as fruit ripens. All animals depend upon a supply of vitamin A of which carotene is precursor, for maintenance of their metabolism and growth. The few hundred naturally occurring carotenoids are generally insoluble in water, but dissolve in fat solvents.

There are two classes of carotenoids, the hydrocarbons or carotenes and the oxygenated or xanthophylls. The chromophonre consists of a chain of conjugated carbon-carbon double bonds joining, in the case of beta-carotene, two beta-ionone rings. Increasing the number of these bonds progressively causes a displacement of light absorption towards longer wave-lengths into the blue region of the spectrum, thus increasing apparent redness opening the ring, as in lycopene, further increases redness.

Examples of carotenoid occurrence in plant products

S.No.	**Carotenes**	**Occur in**
1.	Alpha-carotene	Carrot, lemon, water melon
2.	Beta-carotene	Banana, jack fruit, maize, mango, papaya, pumpkin, carrot, spinach
3.	Lycopene	Tomato, water-melon
S.No.	**Xanthophylls**	**Occur in**
1.	Capsanthin	Red pepper, Red chilly, capsicum
2.	Violaxanthin	Orange juice, red pepper, spinach
3.	Lutein	Spinach
4.	Zeaxanthin	Red pepper
5.	Cryptoxanthin	Red pepper, orange

Carotenoids can be extracted from plants using an organic solvent followed by solvent evaporation. Many crude extracts have been found to be unstable as colourants because they contain many other fat soluble plant components. Hence they have to be refined. Tomato extract is available and also carrot as oil-soluble and water-miscible oleoresins.

Annatto is another exception. Three methods can be used to extract it from the seed pericarp of the Bixa orellana. The oil-soluble extract contains the cis and trans forms of diapocarotenoid bixin as well as thermal degradation products. Oil extraction removes bixin from the seed cover, but solvent extraction results in the purest form of the pigment. Alkaline extraction results in the conversion of bixin to the water-soluble norbixin. The oil-soluble pigment is used to colour yellow spreads, oils, fats, cakes, confectionery coatings and ice cream. Water-soluble norbixin is capable of binding with proteins and is therefore useful for incorporating into the cheese making process.

Paprika made from the chillies, which evolved subtropical and tropical regions of many of the developing countries, is more valued for its pungency than its colour. Four types of paprika products are commercially available. These are : dried paprika powder, paprika oleoresin, water dispersible oleoresin and debittered paprika oleoresin. The colour is more stable to heat and light and is used extensively in soup and meat products as well as in cereals, baked goods, cheese, sauces and condiments.

Saffron has a long established historical use, and the major source of the colour and flavour are the stigmas of the crocus sativus. Many carotenoids have been isolated from saffron. The major fat-soluble pigments are lyropene, alpha-carotene anxanthin. However, the major pigments are the water-soluble crocetin and its ester crocin.

Carotenoids available in the pure form are beta-carotene, apocarotenal, apocarotenal eter and canthaxanthin. These are the manufactured colourants now termed nature identical. They cover the colour range from yellow through orange to red. They are available in oil-soluble and water dispersible forms, and are therefore suitable for use in a very wide range of products. However, their use has not gained world-wide acceptance.

FLAVONOIDS

Anthocyanins

There are two types of flavonoids, the anthocyanins and the anthoxanthins. The former are of greater importance in food. As glycosides of anthocyanidins they have a flavillium structure. They are water soluble and, being highly reactive are readily oxidized or reduced, the glycoside linkages under going hydrolysis. They may also form salts with acids or bases. These pigments are responsible for many of the wide range of red, blue and purple hues of fruits and vegetables as well as flowers. The most common forms of anthocyanidin are pelargonidin, cyaniding, delphinidin, peonidin, malvidin and petunidin. The particular colour depends on the number and orientation of hydroxyl and methyl groups. An increase in hydroxylation leads to an increase in blueness, while an increase in methoxylation leads to an increase in redness.

Table : Anthocyanidins occurring in edible fruit

Anhocyanidins	Occur in
Pelargonidin	Banana, radish, potato
Cyanidin	Apple, blackberry, sweet cherry, fig gooseberry, mulberry, onion, peach, peas, raspberry, red cabbage
Cyanidin plus	Black currant, red currant
Delphinidin	Passion fruit, pomegranate, french beans
Cyanidin plus Peonidin	Plum, sour cherry

Anthocyanins are more stable in an acid environment than in one which is neutral or alkaline. In pelargonidin chloride, the molecular structural transformations occurring with pH are shown below. At pH 1 to 3 this pigment exists as the red oxonium ion, while the hydrated form between pH 3 to 7 is a colourless pseudo base. At higher pHs the purple anhydrobase is formed, but this ionizes above pH 10 and becomes blue.

Anthocyanins degrade on heating upto 90 % of the red pigment in straw berries is lost in jam making. Moderate concentrations (500-2000 ppm) of SO_2 degrades the anthocyanin pigments. The presence of oxygen or ascorbic acid contributes to increased rates of anthocyanin degradation.

Anthoxanthins

There are many anthoxanthin (flavones). Members of this class of flavonoid are colourless in acid but pale yellow in an alkaline medium. Possibly the most common anthoxanthin is quercertin. Which has been found to occur with myricetin. Their structures are show below :

First isolated from the oak, quercetin is also found in onion skins, black carrots, prunes, apricots, corn, apples and tea leaves. The paleness of anthoxanthins restricts their contribution to overall colour is very less, hence they have not been widely studied as constituents of fruits and vegetables. They complex with aluminium to form a yellow colour and with iron to form brown.

As additives

There are several patents concerned with the extraction and stabilization of anthocyanin colourants from natural sources. Tissue culture is a promising source of natural anthocyanins.

Applicable products will probably have a pH less than 3.5. These include fruit drinks, purees and preserves. Among the various plant sources for the pigments commercially available or suggested, are grape juice less, wine grape skins and drid grape extract, roselle (*Hibiscus, sebdariffa*) etc.

Tannins present in anthocyanin powder additives can interact with hydrocollids. The tannins are precipitated when used in gelatine containing products. They can, however, be used in other gel systems. Other product applications include, low pH, milk shakes and beverages, chewing gum, fruit chews etc. Modification of processing conditions can make their use successful in panned goods, hard candies, biscuits and cake icings and jams.

Other colours obtained from the natural colourants

1. **Betalaines** : There are two types of water soluble betalaines. These are the strongly coloured, purpole-red betacyanins, and the yellow betaxanthins or vulgaxanthins. Their natural food product source is the beet root, and the most studied variety is the red beet. Beetanin is the major pigment, comprising upto 95 % of the total betacyanin content of beet. The major yellow pigments are vulgaxanthin I and II which themselves can be derived from betanin. The red to purple colour of the vegetable beet appears to be controlled by the blend of these two pigments.

As the pigment is ionic, colour intensity depends upon pH, but it is reasonably stable between pH 3.0 and 7.0. The most stable range is between pH 3.0 and 7.0. The most stable range is between 4.0 and 5.0 and removal of oxygen increases stability. As slightly lower and higher pHs it is rather bluer, but above pH 10 it changes when it is present in beet juice, and this form of the pigment is frequently used for products. Beet powder having a water activity 0.12 and a moisture content of 2 % has been recommended for optimal storage. A comparison of various methods of beet powder production has shown that the drum-dried product is slightly more stable than the conventional air-dried product. The freeze dried product is less stable, probably due to non-inactivation of the native enzymes.

Common product application for beet colour include yoghurt, sherbet, ice creams, frozen fruit desserts, candies and puddings. The pigment is easily added to candies in glycerol or propylene glycol. Excellent storage stability of the colour has been found to occur in candies because of their low water activity. Performance of beet juice powder has been described as satisfactory for products such as fruit chews and candies, cream, ice cream and table jellies. It is not recommended for inclusion in pectin and starch jellies, bakery products and jams.

There are several processes have been patented for the extraction and stabilization of beet colour. Tissue culture shows promise for producing natural betalaines.

2. Curcumin (Turmeric) : The yellow colouring matter curcumin is obtained from the roots of the dried, ground rhizome of the turmeric plant. Turmeric is used extensively as a versatile spice in vegetarian and non-vegetarian dishes. The pigment is not soluble in water, and is often used in colloidal dispersions. Various forms of the pigment are available. These include; the ground powder from the root, which contains both colour and flavour; the purified powder; and purified extracts, which may be water-miscible, oil-soluble, or oleoresins.

Curcumin is oil-soluble, has good oxygen and heat stability, but is sensitive to light. The deflavoured forms have many applications and can be used, for example, in baked goods, frozen disserts, beverages, margarine and salad dressings. Water and oil-soluble or miscible versions are commercially available.

3. Colours from different flowers : Many flowers are heavily pigmented and may be suitable sources of food colours. The possible sources are marigold, poppy and sunflower seed husks. Red and yellow carthamin pigments can be extracted and manufactured from safflower petals. Marigold is available as a blend with paprika. Water extractions of the dried calyces of *Hibiscus sebedariffa* (roselle) produces a brilliant red colour. This maybe found suitable for addition to juices, carbonated drinks and preserves.

Although the colouring of foods with natural compounds is considered to be desirable for various reasons, their use is limited at present. Currently the use of natural colourants is limited due to their instability, low tinctorial power or price disadvantage. However, a few substances, notably the carotenoids, have been successfully incorporated into specific products.

FOOD TECHNOLOGY – SAFETY CONSIDERATIONS