Food science and technology at the Defence Food Research Laboratory

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About 30 years ago a number of laboratories under the Defence Research and Development Organization were set up to cater to the specialized needs of the Defence Forces. Among them was the Defence Food Research Laboratory (DFRL) established at Mysore in 1961. From a very small beginning, this laboratory has now grown into a well-equipped research centre that looks after problems relating to operational as well as peacetime Service rations.

The Armed Forces in India consume on an average annually about 0.4 million tonnes of dry supplies consisting of grains, pulses and animal food, 13,000 tonnes of processed and other foods, and 0.2 million tonnes of fresh items including fruits, vegetables and meat. Feeding them is thus a major task that requires appreciation of the problems involved in procurement, transportation and storage of food to ensure that the items reach the troops in palatable condition and that the men are provided with diets commensurate with their physical fitness under a variety of climatic conditions. In the early sixties topics like the development of a compo pack and of survival rations used to be very prominent areas of

Some traditional Indian foods processed and preserved in ready-to-eat or instant form

Item	Moisture content (%)	Method of processing/ preservation	Mode of rehydration	Rehydration time (min)	Shelf-life (months)
I. Ready-to-eat					
Kheer, idli, avial, upma, peas-*paneer*, whole meal	60 –80	Thermal processing in cans	Only warming	Nil	6 –12
Pulav, halwa, alu-cholay, rajma, stuffed parothas	35 –70	Thermal processing in cans and retort pouches	Only warming	Nil	6 –12
Chapati	25 –30	Chemical preservation using sorbic acid and in-pack pasteurization	Only warming	Nil	6
Fruit bars – mango, banana, pineapple, etc.	10 –15	Hot-air drying	None	Nil	6 –12
Fruit slices – mango, banana, pineapple, etc.	25 –30	Intermediate-moisture food technology	None	Nil	6
Sweet meats – *chikki*, *modaka*, *holige*, cashew and coconut *burfi*	4 –12	Conventional with chemical preservation using sorbic acid where necessary	None	Nil	6
Compressed cereal bars – sweet and savoury	3 –5	Deep-fat frying and compression	None	Nil	12
II. Instant/quick-cooking					
Dehydrated curried *dals* and vegetables, *khichdi, pulav, sambar, avial, upma* and *halwa* mix	4 –8	Hot-air drying, deep-fat frying and roasting	Simmering in 1.5 – 3.5-times boiling water	5 –10	12
Dehydrated omelette and scrambled egg mix	3 –4	Spray drying	Soaking in 2.5-times water and frying	10	12
Fruit juice powders – mango, pineapple, grape	1 –1.5	Freeze drying	Mixing with 5-times cold water	<1	12
Curd powder	3	Spray drying	Blending with 2.5 – 3-times cold water	<1	6
Fruit-flavoured milk/*lassi* beverage mixes	2 –3	Spray drying	Blending with 4 – 5-times cold water	<1	6

R&D work. During the last two decades the shift has been towards convenience foods, lighter packaging materials, nutrition under stress, and quality assurance.

Product/process development

DFRL has developed a number of new processing methods and products that suit the Indian palate. This involves identifying the qualitative requirements of users, modifying the products to suit changing requirements, developing new processing methods if necessary, conducting storage studies to assess the useful life of the products, carrying out field trials to test their behaviour and acceptability, evolving quality-control measures and laying down standards, and finally locating trade sources of supply from whom the users can obtain their requirements.

From the point of view of Services personnel, the most essential requirement of a processed food, apart from compactness, light weight, long shelf-life and compatibility with the dietary habits of the personnel, is that it should be in a ready-to-eat form or require only simple reconstitution in water at ambient or higher temperature in the shortest time. To achieve this, three major techniques have been employed. These are chemical preservation along with control of water activity, dehydration, and thermostabilization.

Preserved chapatis and bread

More than 80% of the wheat produced in the country is consumed in the form of *chapatis*. It also forms a staple ration item of the Indian Armed Forces. *Chapatis* preserved in ready-to-eat form are therefore an important requirement, particularly in areas where facilities for cooking are limited or non-existent. DFRL has pioneered development of technology for both short-term (10–14 days) and long-term (6 months) preservation of *chapatis* by incorporation of sorbic acid. Short-term preservation, which involves the use of a preservative mixture containing sorbic acid and citric acid and packaging in polyethylene pouches, is easily adoptable in any Army kitchen, and has made it possible for troops to carry *chapatis* on patrol duties. The product has also been improved in texture, flavour and acceptability by incorporating fat, milk powder, oleoresins of cumin and cardamom, potato flour, etc.

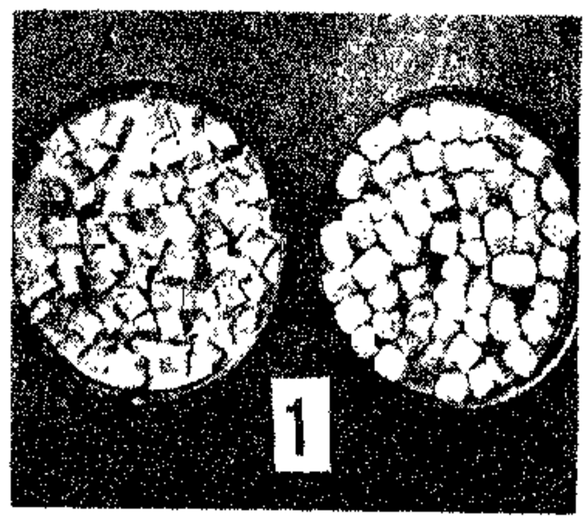
Bread is an important component of the daily menu of naval personnel. It has a very limited shelf-life of 2 days under ambient conditions. A fungistatic wrapper containing sorbic acid used with an overwrap of paper–polyethylene laminate was found to preserve oven-fresh bread for 7–10 days for use on board submarines and ships. DFRL has been regularly supplying wrappers to the Navy.

Quick-cooking/instant dehydrated foods

The traditional Indian diet has three important components, viz. rice, pulses and vegetables, and sometimes some meat. All these require prolonged cooking, especially at high altitudes, and therefore cannot find a place in ration packs. Further, vegetables and meat are bulky and heavy, and have a very short shelf-life owing to their high moisture content. DFRL has developed precooked dehydrated foods with short reconstitution time and long storage life. These can be rehydrated and used, or employed in making traditional convenience foods like *pulav*, vegetable curry mixes, *avial* mix, curried *dals*, etc.

Conventional dehydration by hot-air-cabinet drying at 60–70°C requires considerable time to bring the moisture level in the product down to 5–6%, and adversely affects colour, texture, flavour and reconstitution. A high-temperature, short-time pneumatic drying technique has been developed for rice, pulses and vegetables, which gives significant reduction in drying and rehydration times and improvements in product quality. For certain vegetables not amenable to this technique, predrying treatments with simple, inexpensive additives like common salt and cane sugar were found to bring about improvements in colour, texture, rehydration and shelf-life.

A process based on cooking, flaking, conditioning and drying has been developed to prepare instant *dals* which can be reconstituted within one minute. Freeze-drying, earlier used only for expensive pharmaceutical products, has been successfully utilized for drying a number of piece-form foods. Freeze-dried fruit-juice powders are superior in acceptability, convenience of use, and overall quality.



Conventional hot-air-dried (*left*) and high-temperature, short-time pneumatic-dried potato dice (*right*). HTST drying of many vegetables and pulses significantly reduces drying and rehydration time.

Intermediate-moisture foods

In contrast to low-moisture dehydrated foods (moisture content below 5%), which require rehydration, a new class of foods called intermediate-moisture foods (IMF) have emerged in recent times which need no preparation prior to consumption. They are characterized by a water activity low enough to prevent growth of yeasts and moulds. This is usually achieved by addition of an osmotically active solute such as glycerol, sucrose, glucose or salt and an antimycotic such as propylene glycol and/or sorbic acid. IMF are soft and moist enough to be eaten as such and yet keep for a long time without refrigeration or thermal processing. The method has been used in DFRL to develop, for the Services, ready-to-eat products from a variety of fruits in place of the heavy and bulky tinned fruit. The process is simple, requires low energy, and can be adopted by small-scale industry.

Thermostabilized foods

Tinned foods. The Armed Forces are

the single largest buyer and consumer of tinned foods in India. As the indigenous canning industry supplied canned foods that were generally of the kind that suited Western tastes, DFRL standardized process parameters for canning a number of traditional Indian dishes for specific use by the Services. In addition, the increasing cost of imported tin plate and its decreasing availability led to development of alternative processes and packaging that use indigenously available packaging materials for the purpose. One outcome of this are the 'retort-pouched foods'.

Retort-pouched foods. Easy availability of packaging materials of choice and advanced laminating techniques have resulted in successful commercial application of flexible packs for retort processing in developed countries. Retort pouches have several advantages over the conventional open top seam (OTS) cans: they require shorter processing time, which is energy-saving and reduces thermal damage, resulting in better retention of flavour, colour and texture of the foods; they are lighter, less bulky, and require less storage space; and they are easily disposable.

DFRL has pioneered standardization of processing techniques using indigenously available polypropylene for in-pack sterilization of several ready-to-eat traditional Indian dishes. This has opened up a new field.

Aluminium cans. Aluminium containers are lighter than tin containers; they do not rust, are of low toxicity, can be easily opened by hand, and can be recycled. However, all over the world, use of aluminium containers has been mainly in the beverage and soft-drink industry, and their use in food canning, which requires pressure processing, has been very limited for want of suitable alloys and the special processing equipment needed to ensure gentle handling and minimal thermal stress during heating and cooling.

India possesses 80% of the world's bauxite reserves, and although present production of aluminium is only 1.5% of total world consumption, the country has the potential to become one of the world's major aluminium producers.

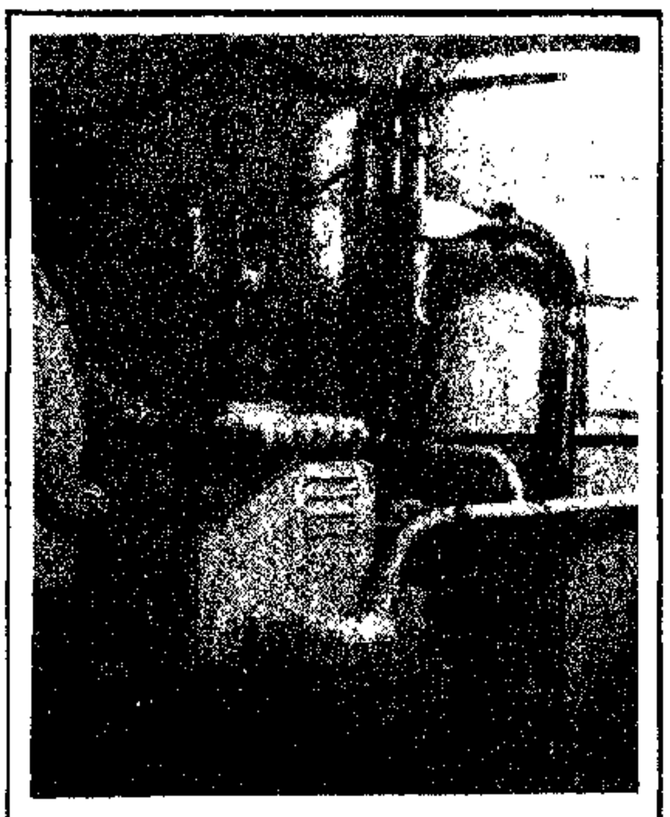
No R&D effort has been made in the country towards the use of aluminium containers instead of tin containers for canning Indian foods.

Use of aluminium in packaging is presently confined to foils, laminates, collapsible tubes, bottles for perfumes and pesticides, and, to a limited extent, cans for beverages. Preliminary pack tests with a few foods carried out by DFRL using cans fabricated in collaboration with Indian Aluminium Company and a few leading can manufacturers have given encouraging results. In collaboration with the Defence Metallurgical Research Laboratory (DMRL), Hyderabad, suitable alloys for containers and lids are being developed and tested. Introduction of the aluminium can for foods can be expected in the next two or three years.

Rations to meet specific operational needs

Emergency ration for the Army. Many Army operations require the carrying of compact, light-weight, ready-to-eat concentrated foods of high calorie content. Such compressed, dehydrated foods, which require no preparation, have inherent advantages in that compacting gives extended shelf-life and reduction in bulk and consequently economy in transportation, storage space and packaging material.

DFRL has developed several savoury and sweet compressed, ready-to-eat cereal bars using deep-fat-fried ingredients. These have a shelf-life of more than one year under ambient conditions in flexible packaging. Troop trials have shown that the bars are acceptable as individual ration for subsistence during emergency. A compo ration survival pack containing the compressed bar has also been formulated.



Egg *mélange* being dried using a laboratory-model spray drier. Spray drying is most economical for continuous drying of several liquid foods and for microencapsulation of flavours.

Survival ration for the Navy. Any survival/emergency ration meant for use by ship-wrecked sailors at sea should be such as to spare body water to the maximum. The principal requirement under such situations is for drinking water, which cannot be obtained from sea water and has to be supplied along with the ration; food is only to prevent the physical deterioration consequent upon total fasting and to sustain the morale of the survivor. Survival performance has been shown to be better on a low-fat and low-protein ration, and most countries favour an all-carbohydrate ration. DFRL developed a survival ration in the form of a soft fudge-type cocoa-flavoured confection, which contains less than 1% each of protein and fat, consists mainly of carbohydrate, and has a shelf-life of more than three years in flexible packaging. Limited trials by the Navy under near-survival conditions have shown the superiority of the ration to the existing one of boiled sweets and milk toffees.

Compo ration. A one-man compo ration based on quick-cooking, precooked dehydrated convenience mixes has been developed to replace the five-man compo ration used by the Army as patrol ration since the latter failed to meet logistic requirements. The new compo ration has been put into production and extensive trials under operational conditions have shown its acceptability and worthiness.

Preservation and storage of foods, packaging

Very little information is available on factors that influence flavour and texture of Indian foods. Flavour often deteriorates in processed foods long before their nutritive and other functional properties are lost, and this is one of the limiting factors in the shelf-life of processed foods.

DFRL has conducted extensive basic studies to identify volatile and non-volatile products in stored dehydrated vegetables like carrot and onion, and to identify the role of lipids, water activity, additives and pretreatments in colour, flavour and texture retention. Chemical and nutritive changes during storage in dry rations like pulses, rice and milled products have also been studied. In dry fruits, good correlation has been established between organoleptic quality and formation of malonaldehyde during storage. Factors that affect flavour and texture of *chapatis* during preparation and storage were studied and suitable preventive treatments devised.

Storage of bagged commodities like sugar in naval depots, and of rice, pulses, *atta* and other cereal products in Army Service Corps depots in coastal and northeastern regions, where high humidity prevails, is a major problem. With absorption of moisture, sugar tends to become sticky, lumpy and syrupy, while the other commodities are subject to fungal attack and infestation. After extensive trials DFRL has developed suitable simple stack encapsulation methods using polyethylene tents. These have proved very effective in checking ingress of moisture in bagged sugar. The efficacy and suitability of the method for the other commodities are under test.

While processed fruits and vegetables are the main component of operational rations, a variety of fresh fruits and vegetables form part of daily supplies in normal Service rations. In the Navy, large quantities of fresh fruits and vegetables have to be stored on board ships and submarines in the limited storage facilities available. Under such conditions deterioration due to overripening or senescence poses a serious problem. It is known that ethylene, which acts as a plant hormone, is generated in varying amounts by most fruits and vegetables and plays a significant role in regulating ripening. Gradual removal of ethylene from the storage atmosphere using ethylene absorbents is known to extend the shelf-life of fresh fruits and vegetables in both cold and ambient storage. This method is used in some developed countries. Ethylene absorbents are presently not manufactured in India and have to be imported at high cost. DFRL has carried out extensive trials in the laboratory and on board naval ships to evaluate the efficacy and utility of an ethylene-absorbing formulation containing potassium permanganate. A suitable indigenous formulation that has been developed is cheaper and effective, and is presently under evaluation by the Navy. A similar formulation suitable for use by the Army is also being developed.

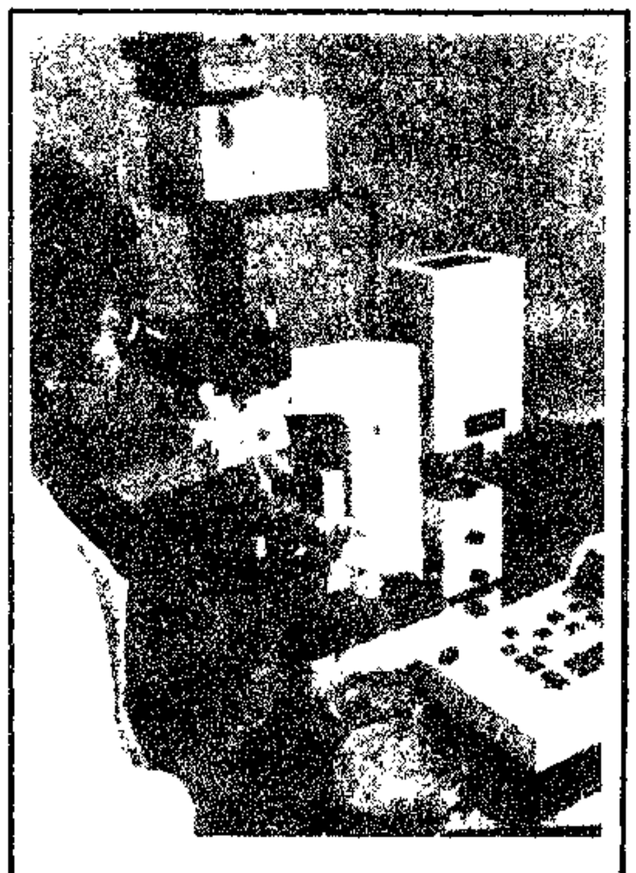
Several processed convenience foods developed in DFRL showed high microbial loads during large-scale production. Permissible doses of gamma radiation were effective in increasing the shelf-life of the foods. Irradiation ensures safety without affecting organoleptic quality. Products tested included wheat flour, *chapatis*, spices and convenience foods like *pulav*, *khichdi*, *kachodi*, curried *dals*, etc. The scope for the application of the technique in prevention of sprouting in potatoes and onions, which form part of Service supplies, is also being studied.

The functional requirements of packaging materials used for Defence food packaging applications are more stringent than those for the civilian market as the packages have to withstand extreme climates and adverse storage, transportation and handling conditions. The escalating cost of conventional cans and bottles and transportation costs have necessitated the use of flexible plastic materials wherever possible. DFRL has contributed significantly to evolving standards for indigenously available packaging materials, utilization of available packaging materials for Service rations, and development of new types of packaging for specific purposes in collaboration with industry.

Nutritional and toxicological studies, microbiological standards

Biochemical and animal experiments have been done to asses the nutritional requirements of Services personnel under various combat situations and the adequacy of the rations supplied to them. Studies have been conducted to evaluate the influence of dietary protein and other factors required to overcome or to acclimatize to such stress conditions as high altitude, injury, low caloric intake, etc. For example, in rats under the stress of an inflicted injury, wound healing was shown to be accelerated by administration of glutamic acid, which is not normally considered to be an essential amino acid.

Long-term feeding experiments showed no impairment of longevity, growth rate, food efficiency ratio, etc. in rats fed *chapatis* preserved with sorbic acid. Histopathological examination also proved the safety of sorbic acid-preserved *chapatis*. DFRL is also studying the toxic effect of plasticizers such as the phthalates used as additives in flexible packaging materials like PVC bags, in which sterile potable water is packed as part of Air Force survival packs.



Microbiological analysis of processed food samples—food safety and quality assurance.

New methods of processing and packaging must be supported by knowledge of the behaviour of residual microflora during processing and storage, which will help lay down standards and ensure safety of consumption. In DFRL, the microbiological quality of several processed foods has been assessed, standards laid down, and processing stages vulnerable to contamination have been pinpointed.

Besides working out standards for ideal slaughterhouse practices and

conditions of ageing of meat for optimum tenderization and microbiological safety, the laboratory has also developed simple field kits based on endotoxin assay for rapid microbiological monitoring of raw meat in the field. In the case of canned curried meat, thin-layer chromatographic tests based on chemical markers like free fatty acids have been found to be useful in evaluating the quality of the mutton used.

Packaging food for space mission needs. Laboratory-model vacuum/gas packing equipment for packing foods in rigid and semi-rigid plastic containers.

Biotechnology

The use of microorganisms as an alternative to seeds for the production of fats and oils is becoming increasingly attractive, particularly in countries where the conventional starting material is in short supply. DFRL has screened several species of *Fusarium* and identified one suitable for production of edible fat. Conditions such as carbon : nitrogen ratio were optimized to maximize biomass yield and oil content. The use of various agricultural and food-processing wastes is also being explored.

The laboratory has also been conducting studies on the role and use of microbial and plant enzymes in food processing and storage. Notable among them are use of papain from papaya latex in reducing cooking time of dehydrated mutton and pulses, fungal pectic enzyme in clarifying fruit pulps prior to concentration or dehydration, fungal glucose oxidase in desugaring egg *mélange* prior to drying to improve shelf stability of egg powder, and plant (fruit and vegetable) polyphenol oxidase and peroxidase, which are responsible for browning and off-flavour in fresh and processed foods.

Space food

DFRL is the only institution in the country where R&D work pertaining to space food is being carried out. The work involves identification, formulation and processing of Indian foods suitable for use on manned space missions, and development of suitable packaging systems. In active collaboration with the Soviet space agencies and the Indian Space Research Organization (ISRO), DFRL carried out extensive testing of several processed foods developed in the laboratory and identified a few which were subsequently used and greatly appreciated by the cosmonauts on the successful Indo-Soviet Joint Space Mission, Project Pavan, in April 1984. The laboratory also conducted collaborative studies with the US National Aeronautics and Space Administration (NASA) and ISRO on several foods for use on board the space shuttle for the INSAT-1C payload specialist, and to evaluate products of Indian origin for their suitability on manned space flights.

Technology transfer, other roles

DFRL, being primarily an R&D unit, has only limited production facilities and any large-scale manufacture and supply has necessarily to be done in collaboration with private industry through technology transfer. In the last five years 58 firms have taken know-how for 25 products from DFRL for commercial exploitation and to meet Defence requirements. Production of 10 products has been established. Several other organizations have also drawn upon the facilities and expertise of DFRL in processed food supply to meet specific requirements such as those of various mountaineering expeditions, including the Indian Mount Everest Expedition, rowing expeditions, motor rallies, the Border Security Force, and all the Indian Antarctic expeditions from 1980 till date.

The scientists of the laboratory have been actively associated as members of various committees on food and agricultural products of the Bureau of Indian Standards concerned with Civil Standards and of the Technical Standardization Committee concerned with Defence Standards. They have also contributed to the formulation of specifications for various fresh and processed foods.

For the last several years, the laboratory has been conducting three training courses every year for officers and staff of the Supplies and Transport Directorate of Army Headquarters engaged in food procurement and quality control. The courses provide instruction in the latest developments in food science and technology and modern analytical methods of food analysis.

India is a member of the Food Study Group of the Commonwealth Defence Science Organization, which has presently 15 member countries. DFRL has been participating in the triennial meetings of the Group to exchange views and keep abreast of developments in other member countries in the field of Defence food science.

Ration development for the Defence Services is a continuing exercise influenced by new developments in food science and technology. New processing techniques developed in India and elsewhere are expected to have an impact. These include aseptic processing, extrusion cooking, membrane concentration techniques, immobilized-enzyme technology, controlled and modified-atmosphere storage and microencapsulation techniques. DFRL has an ambitious future programme involving these techniques and aimed at improving the quality and stability of foods supplied to India's Defence Services.

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