UNIT 11 FOOD FORTIFICATION

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11.0 OBJECTIVES

After reading this unit, you should be able to:

• list the advantages, limitations and risks in fortifying foods;
• describe the methods of food fortification;
• define the importance of fruits and vegetables in human diet;
• decide the points to be considered for fortification of fruit and vegetable products; and
• prepare fortified fruit and vegetable products.

11.1 INTRODUCTION

All living beings require nutrients to perform various functions of life. While plants can prepare them from simple chemicals present in the soil and the environment, higher organisms can not perform this synthesis and have to depend on plants and other animals for their nutritional requirements. Body performs several functions related to growth and development and it has to cope up with the normal wear and tear process. Several nutrients are required for promoting these activities which should be available in sufficient quantity. But no single food contains all the nutrients; their nature and quantity vary with the source. Improper diet may result in deficiency of one or more of these nutrients. Nutritional deficiencies reduce mental and physical efficiency of people and increase their susceptibility to diseases. It is for this reason the Indian Constitution enshrines in its Article 47 that “the state shall regard the raising of the level of nutrition --- as among its primary duties”. In this chapter we will see how fortification of fruits and vegetables could improve the nutritional status of people.
11.2 NECESSITY OF FOOD FORTIFICATION

11.2.1 Nutritional Requirements of Man

Human body requires at least 45 nutrients; 5 macronutrients (protein, fat, carbohydrate, water and oxygen) and 40 micronutrients, which include 13 vitamins (A, C, D, E, K and eight members of vitamin B group) and 17 minerals (Ca, Cl, Fe, K, Mg, Na, P, and S whose requirements are 1 µg to 1 g per day, and Cr, Co, Cu, F, I, Mn, Mo, Se, and Zn which are required in traces). Water and oxygen are not regarded as nutrients because they are present in foods and readily available for body use.

Nutrient requirements vary from person to person and are influenced by factors like age, sex, height, physiological state, physical activity and environmental conditions. No single food contains all 45 nutrients. Food items included in daily diet should be carefully selected so that the nutritional requirements are fulfilled.

11.2.2 Pattern of Food Consumption in India

In order to survive, man’s main effort in ancient times was to collect enough food for his requirements and store them for difficult periods. But he soon realized that foods from different sources differ in nutritive value. Through experience over ages, he selected his foods carefully to meet his nutritional requirements and to ensure a good health. It led to the development of dietary habits. Food habits were also influenced by the foods available in the locality and practices prevalent among them.

Indian Council of Medical Research has divided the foods consumed in India into five groups: (1) cereals, grains and their products, (2) pulses and legumes, (3) fruits and vegetables, (4) milk, meat, egg and their products, and (5) fats and sugars. Cereals constitute major part of the Indian diet. Being rich in carbohydrates, they contribute up to 80 per cent of daily energy intake and about 50 per cent of daily protein intake of an average Indian. They are also dietary source of minerals like calcium, iron and vitamin B.

Pulses and legumes are the major source of proteins in the Indian diet. They are also rich in vitamin B.

Fats and oils and sugar/jaggery serve essentially as source of energy. They improve palatability of foods. Further, fats and oils provide essential fatty acids and act as carrier of fat soluble vitamins. For a good health, maximum of 20 per cent calorie requirements should be derived from fats and oils.

Milk holds a high place in the Indian diet. Milk proteins are of very good quality. It is rich in calcium and riboflavin and is a good source of many other nutrients. But it is deficient in iron and vitamin C.

Fruits and vegetables are rich in vitamin C, beta-carotene, crude fibre and minerals. In general, they are not regarded as a good source of calories and proteins; dried fruits, tree nuts, olives, avocado, beans and peas are some of the exceptions to this. Roots and tubers like potato, tapioca, yams, sweet potato, etc., contain substantial amount of starch and thus contribute substantially to the dietary calories.
Eggs and meat are good source of proteins and vitamins of group B. Their proteins are of very good quality. They are rich in calcium and riboflavin and are good source of many other nutrients.

### 11.2.3 Strategies to fulfil Nutritional Requirements

Inadequate and insufficient diet may result in deficiency of one or more of these nutrients. Often deficiency of one nutrient results in incomplete utilization of other nutrient(s) present in food. Nutritional deficiencies observed in India are: (i) protein-calorie malnutrition, (ii) vitamin A deficiency, (iii) iron deficiency, (iv) iodine deficiency, and (v) deficiency of vitamins of group B.

The challenge of nutritional deficiency can be overcome by increasing availability of nutrients through higher and diversified production of food and careful planning of diet. Diet planning becomes complicated because (i) foods differ in their nutrient composition, (ii) method of processing/preparation may cause losses, (iii) foods may suffer from certain deficiencies specific to a region such as iodine deficiency in Sub-Himalayan region, (iv) certain group of people may have special requirements of some of the nutrients, and (v) economic status of a group of people or population may limit the choice of food items. Further, all the nutrients present in a food may not be biologically available due to (i) the presence of anti-nutritional factors like trypsin inhibitor, (ii) their poor solubility, (iii) destruction of nutrients in the gastrointestinal tract, (iv) poor digestibility of a food source, or (v) varying degree of losses during preparation/processing.

Other methods of controlling malnutrition are (i) nutrition education, (ii) dietary diversification, (iii) dietary supplementation, and (iv) food fortification. Nutrition education and dietary diversification take long time to show results. Dietary supplementation is a very effective method but it is used in the cases of acute deficiencies in high-risk groups and is expensive. Food fortification is a simple and inexpensive method of fighting the problem of a nutritional deficiency prevalent in a known region or segment of population.

### 11.3 FOOD FORTIFICATION

The term food fortification is defined as a process of adding one or more dietary essentials to a food. Various terms are used to describe the process of addition of nutrients to foods which are discussed below.

i) **Enrichment:** This term is used for a process in which the level of one or more nutrients, already present in a food, is moderately increased by addition to make its level higher so that it becomes a richer source of that nutrient.

ii) **Fortification:** According to WHO fortification is the addition of nutrient(s) to a food or an article of diet to improve the quality of the diet of a group, community or a population. Level of nutrients added may be more than those found in original or comparable food. Objective of fortification is to help correct nutritional deficiencies in a specific population. Fortification may also include addition of small quantities of nutrient to improve intake of that nutrient by a population.
Product Utilization

iii) **Nutrification:** It is a general term used to indicate the practice of adding vitamins and minerals to compounded and processed foods used as entire meals or meal-replacers, viz., infant formulas, instant breakfast foods etc.

iv) **Restoration:** Loss of some of the nutrients takes place during handling, transport, processing and storage of foods which cannot be prevented. Restoration refers to the replacement of the nutrients lost during the above processes.

v) **Standardization:** There may be natural or seasonal variations in the nutrient composition of foods. The term standardization refers to the process of adding nutrients to compensate for the above variations and bring them to a predetermined level. It is helpful in meeting the requirements of nutritional labelling.

vi) **Supplementation:** This term refers to the process in which nutrients not present normally or contained only in very small quantities in a food, are added to it.

The above terms are often used interchangeably. Fortification is now a general term used to indicate addition of nutrients to improve nutritional quality of foods.

11.3.1 History of Food Fortification

Probably the earliest recorded attempt of fortification is of 4000 B.C. when the Persian physician Melamus prescribed a diet including sweet wine laced with iron filings for the sailors. In 1833 a French chemist Boussingault advocated addition of iodine to table salt to prevent goiter in South America and thus may have introduced the concept of “food fortification”. Another important observation was made in 1897 when Dutch army doctor Eijkman while working in Indonesia, noted that beriberi was more common in people whose staple diet was polished rice. Vedder and Williams used a crude extract from rice bran, to cure advanced cases of beriberi despite the fact that they were unaware of its active constituent. In 1911, Funk established that the anti-beriberi compound of unpolished rice was an amine. He named this compound as vitamine, i.e., vital amine. Williams continued his work in Philippines and synthesized it. Since this amine contained sulphur, he named it as thiamine, i.e., sulphur amine. A Swiss company, Hoffman-Roche developed a process for adding thiamine, niacin and iron to rice.

Introduction of margarine, a butter substitute, in Denmark led to vitamin A deficiency. Therefore, fortification of margarine with vitamin A was started in 1918. Fortification of flour with thiamine, riboflavin, and niacin and sometimes iron and calcium was started in the United States of America during World War II. Addition of vitamin D to infant formulations and milk and dairy products to prevent rickets among children are other examples of early efforts of food fortification.

In India, fortification of salt with lysine, iron and vitamin A was tried in 1970. At present, several food products available in Indian market are fortified, viz., common salt is being fortified with iodine salts, vanaspati with vitamins A and D and bread with lysine. For fortification of salt with iodine, potassium and sodium salts of iodide and iodates are used. They are added at the rate of 30-200 mg per kilogram of salt, depending on the amount of salt consumed per
day by a population. In India, salt consumption is 15 gm per day per person. Therefore, potassium iodate is added at the rate of 15 mg per kilogram of salt.

11.3.2 Advantages of Fortification
Food fortification does not require people to change their dietary habits and it does not alter organoleptic qualities of foods. Therefore, it is socially acceptable. The other benefits of fortification are (i) minimum risk of excess intake of the nutrient, (ii) safe, quick and cheap method of ensuring availability of a nutrient, (iii) introduction through existing marketing and distribution system without any extra effort, (iv) every segment of affected population gets necessary amount of the nutrient, and (v) synthetic nutrients used in food fortification become available just after their absorption in the intestinal tract.

11.3.3 Limitations of Food Fortification
Food fortification requires knowledge of dietary habits and nutrient intakes in the target group(s). Consumers have to be educated about fortification, particularly if it is causing any change in the sensory qualities of the food or it necessitates any modification in the method of preparation of food at home. Food fortification is a temporary method of improving nutritional status of the people and should ultimately be substituted by balanced diet based on better food supply and food usage.

11.3.4 Safety of Food Fortification
Excessive intake of nutrients may sometimes lead to undesirable interactions with other nutrients. For example, excessive intake of an inorganic element can depress the absorption or utilization of another. Similarly, excessive intake of a strongly reducing nutrient, like vitamin C, can reduce absorption of selenium or carbon and strongly enhance bio-availability of iron. Higher intake of fat-soluble vitamins A and D exert toxic effect, while other vitamins are non-toxic even if ingested at high levels (up to 100 times of recommended level). The safety range is smaller for vitamin A (10 times of RDA) and iron (5 times of RDA). Level of food fortification generally ranges between 15 to 25% per serving, which is much below the critical levels.

In fortified food products, the level of fortification must be documented. Level of nutrients which amount to excessive intake should be established scientifically and the consumers should be made aware of such levels and their adverse effects. Response of consumers on quality of fortified foods, nutritional benefits or other relevant information must be collected and used to improve the product.

11.3.5 Methods of Fortification
Methods used for food fortification with nutrients are as follows:

i) **Dry mixing:** It is used for foods like salt, beverage powders, cereal products, milk powder, etc.

ii) **Dissolution in water:** The nutrients are dissolved in water or the product and mixed, e.g., fruit juices, beverages, drinks, etc.

iii) **Spraying:** Processed foods that require cooking or extrusion like potato chips, fruit bars, etc.
Product Utilization

iv) *Dissolution in oil:* Oily products such as vanaspati are enriched by nutrients dissolved in oil.

v) *Adhesion:* It is used for sugar fortification. Vitamin A in powder form is adhered onto the surface of the sugar crystals when used with a vegetable oil.

vi) *Coating:* The vitamins sprayed over the grain must be coated to avoid losses when they are washed before cooking. It is generally used in case of rice.

vii) *Pelleting:* It is also used for rice. The vitamins are incorporated into pellets reconstituted from broken kernels.

### 11.4 FORTIFICATION OF FRUIT AND VEGETABLE PRODUCTS

Fruits and vegetables possess rich colour and have varied aroma. They add variety to the food, and improve aesthetic appeal of the diet. Fruits and vegetables are generally consumed for their aesthetic appeal but their nutritional significance is not fully realized by the consumers. They are rich sources of vitamins, minerals and dietary fibre. Dietary fibre (hemicelluloses, celluloses, lignins, oligosaccharides, pectin, gums and waxes) though resistant to digestion play an important role in human health. They do not provide nutrients directly, but low dietary fibre have been associated with diseases like cardiovascular diseases, obesity, diabetes, constipation, bowel cancer, etc. Daily intake of 30 g dietary fibre by a normal healthy adult has been suggested. Fruits and vegetables, in general, contain 1.0 to 2.2 % fibre and contribute up to 50% of dietary fibre. Fruits and vegetables, contribute about 90% of total dietary ascorbic acid, 50% of vitamin A, 35% of riboflavin, 25% of magnesium, 20% each of thiamine and niacin, 20% of fat, 7% protein and 10% of food energy.

Nutritional composition of fruits and vegetables depends on species, variety, location, season and agro-climatic conditions. Moreover, nutrient loss also occurs during storage, preparation and processing. Consumer may not be aware of these changes. Fortification helps in standardizing fruit and vegetable products to a pre-decided level of nutrients. It also enables processors to fortify the products to meet the nutrient requirements of specific group of people such as sport persons and athletes.

#### 11.4.1 Principles of Fortification of Fruit and Vegetable Products

Following points are to be considered before fortifying a product:

1. **Principle of need:** There should be a deficiency/malnutrition in a population which makes food fortification necessary.

2. **Principle of food distribution:** A proper carrier should be identified for fortification programme. Any such carrier that is consumed by a large population should be centrally processed and centrally distributed. Fortified food should be made available to the people who need them at their place.

3. **The principle of stability:** Nutrients should be stable during processing, storage and distribution. To compensate for these losses an overdose of nutrient is added. But for determining overdose, the maximum amount of
Food Fortification

particular food likely to be consumed by an individual per day should be known, and it must be ensured that there is no excessive consumption of nutrient.

4. **Principle of compatibility**: Nutrient being used for fortification should be physiologically and chemically compatible to natural or other food ingredients. It is very important that the added nutrient does not react and remains biologically available.

5. **The principle of camouflage**: Fortification should not cause noticeable changes in sensory characteristics of food products. This is an important point to be considered during fortification.

6. **Principle of economy**: Cost of a fortified product is influenced by the cost of nutrient added, form of the nutrient, shelf life of the product and overages needed to achieve a specified shelf-life. Fortification should not make much difference in the cost of the food product.

7. **Principle of accessibility**: Standards and specifications for fortified food and methods of enforcing them should exist.

8. **Principle of disclosure**: The form and amount of nutrient used for fortification should be declared on the label so that the consumers could know it.

9. **Availability of technology and equipment**: Fortification on commercial scale requires special equipment, proven technology and skilled manpower. They should be available.

11.4.2 **Fortified Fruit and Vegetable Products**

Fruit and vegetable products generally selected for fortification are those which are consumed more regularly and therefore, can serve as a better carrier of nutrients. Beverages, juice concentrates, juice powders, fruit bars, jellies and jams are a few examples of such products. Fortification should ensure that the normal amount of that food product consumed in a day supplies the whole requirement of the consumer for that nutrient.

Retention of nutrients in fruit and vegetable products are affected by the conditions prevailing during processing and storage. Therefore, sufficient overdose should be added to these products.

Information about the nutrient content is given on the label of container on the basis of a serving. The term ‘serving’ denotes that quantity of a food in a meal which is suitable for consumption by an adult male doing light physical activity. Unit of ‘serving’ should be understandable to common consumer, such as cupfuls, teaspoonfuls, etc.

11.4.3 **Fortification of Beverages**

The term beverage includes fruit juices, squashes, nectars, ready-to-serve beverages, carbonated beverages or aerated waters, synthetic juices, fruit juice concentrates and dry instant drinks. Beverages are the most commonly fortified fruit and vegetable products. They are fortified with vitamin C and to some extent with vitamins A and B. For vitamin A, the substance used is beta carotene, which is a precursor of this vitamin and also gives colour to the juice.
Synthetic sources of vitamins are used, though blending with aonla juice as a source of vitamin C and carrot juice as a source of beta carotene can also be carried out. Losses of vitamins may take place during processing. Therefore, contact of fruit juice with iron and copper should be minimized by using stainless steel or glass lined equipments and vessels and juice should be de-aerated before pasteurization.

Vitamins, particularly thiamin, folic acid and vitamin C, are sensitive to heat. Beverages fortified with these vitamins must not be over heated; their temperature should be kept at 90°C or less for a maximum period of 15 seconds. Fortification of beverages with vitamin A, folic acid and calcium pentothenate present problems because these nutrients are very unstable at pH around 3.0, which is normal pH of most fruit juices. Further, solubility of folic acid in water is very low.

Vitamin premix is dispersed in juice/beverage, before homogenization step. Subsequent step of homogenization insures thorough mixing of vitamins in beverage.

Amount of vitamin C added should be such that each serving of 110-170 ml provides about 40 mg, which is the minimum daily requirement of an adult. Since some of the vitamin C may be lost during processing and storage, its 35-70% extra amount is added. In other words, total amount of vitamin C should be 54 to 68 mg per serving.

i) Fortified apple juice

Apple juice contains only 0.2-0.6 mg vitamin C per 100 ml as compared to 9.7-70.0 mg per 100 ml in orange juice. Further, colour of apple juice is light after extraction. But colour of juice becomes dark within 1 hour due to action of enzyme polyphenol oxidase on tannins of juice in the presence of air. Apple juice is fortified with vitamin C to raise its vitamin C content and to utilize oxygen present in the head space. Removal of oxygen from headspace checks oxidation of tannins and thus prevents discoloration of juice. But fortified apple juice, when exposed to oxygen, starts loosing vitamin C at the rate of 1 to 4 mg per 100 ml per day and its colour may again become dark. Therefore, it should be protected from air.

Vitamin C is added at the rate of about 70 mg per 100 ml at the time of extraction when apple juice comes out of press. Excess amount of added vitamin C may get degraded during processing and storage but it ensures that 40 mg of this vitamin per 100 ml remains in the juice.

ii) Fortified orange juice

Vitamin C content of orange juice varies from 27 to 67 mg/100 ml depending upon location of orchard, variety, etc. Therefore, orange juice is fortified so that it provides the minimum recommended amount of 40 mg vitamin C per serving.

iii) Fortified fruit juice concentrates and powders

Fruit juice concentrates and powders serve as base for various fruit beverages. They are easy to store and transport and reduce packaging requirements as compared to juices and other beverages. But during preparation, fruit juices are heated for long period which results in greater loss of vitamins. Therefore, they are fortified. High TSS of concentrates
Food Fortification

protect vitamins and reduce loses during storage. Synthetic orange juice concentrates are prepared using orange pulp and rind. Other ingredients added are gum arabic, cellulose gum, natural and synthetic flavours, artificial colour, potassium citrate and calcium phosphate. It is fortified with vitamin A, B and C.

Fortified fruit juice powders are prepared from fruits like apple, peaches, cherry, etc., by foam-mat drying process. In this process solubilized soy protein and methyl cellulose is added to fruit pulp.

Instant dry mixes of beverages and juice powder are fortified with vitamins by dry mixing. Water dispersible forms of vitamins are used. Mixing must be complete but over mixing should not be done because it results in segregation.

iv) Fortified carbonated beverages

Many carbonated beverages are fortified with vitamin C. During carbonation process, CO₂ expels the air. Removal of air and oxygen increases stability of this vitamin. Fortification of carbonated beverages with vitamin C improves nutritional value of the beverage, and some of it react with and remove residual oxygen from the head space of bottle which extends shelf-life of the beverage. Theoretically, 3.3 ml of vitamin C reacts with 1 ml of air. An overdose of vitamin C should be added to carbonated beverages to compensate for the losses.

v) Fortified banana powder

Banana powder fortified with soy protein can be used as a weaning food for babies. To prepare it, whole soybeans are blanched in boiling water for 30 min, ground into fine paste with 10 times its weight of water and mixed with ripe banana pulp. Ratio of banana solids and soy solids in paste is kept equal. To the blend 100 ppm sodium metabisulphite is added which prevents darkening. The paste is dried to 3% moisture level over a drum drier.

vi) Fortified jellies

To fortify jellies, a concentrated vitamin premix is prepared and some sucrose is added. Fat soluble vitamins are used in water dispersable forms. Vitamin premix is added to the jelly near the end point but before addition of citric acid. Vitamin C reduces the pH of jelly which may prevent their setting. Therefore, pectin jellies are not fortified with vitamin C.

vii) Fortified fruit cloth and fruit bar

Fruit cloth and fruit bars are products prepared from fruit pulp and concentrates by sun drying or drum drying. Fruit clothes from apples, apricots, dates, mango, papaya, etc., are prepared. ‘Amavat’ or ‘Ampapar’ is traditionally prepared in India by sun drying ripe mango pulp in the sheets, the thickness of sheet is gradually increased. The fruit bars can be moulded into different forms. They may be pre-treated with SO₂, viz., 0.5% sodium bisulphite. Sulphur dioxide improves colour and protects vitamin C and beta-carotene. Level of total soluble solids in pulp is raised to about 30% by adding sugar, also reduces drying time. Depending upon requirement, citric acid is added to improve the taste and acceptability of fruit bars. It can be fortified with protein powders (skim milk powder,
Product Utilization

Whey protein isolate, ground nut or soy protein isolate, yeast protein, vitamins and other nutrients. Fortification is done by adding nutrients to the pulp concentrate and then drying it or spread the nutrient premix over the surface of dried fruit material.

🔍 Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
   b) Compare your answers with those given at the end of the unit.

1. How has ICMR classified foods consumed in India?

2. Define term ‘food fortification’.

3. What points should be considered before taking up food fortification work?

4. What is significance of fruits and vegetables in human nutrition?
5. What are the advantages of fortifying carbonated beverages with vitamin C?

6. At what stage vitamin C and vitamin pre-mix should be added to apple juice, instant juice powder and fruit jelly?

7. Discuss the factors which influence stability of vitamin C and beta-carotene in fruit and vegetable products.

11.5 LET US SUM UP

Nutritional requirements of men are varied and no single food can provide all the dietary essentials. It has resulted in various types of nutritional deficiencies. In such cases fortification offers an inexpensive and quick method for combating problem of nutritional deficiencies. People should be educated about needs and benefits of food fortification. Commonly fortified fruit and vegetable products are beverages, fruit bars and jellies which are consumed by a large section of people. Essentially fortification should be done only when it is necessary as proved by scientific studies, should be safe and effective. It should not be used as a marketing strategy.
# 11.6 KEY WORDS

<table>
<thead>
<tr>
<th><strong>Beverages</strong></th>
<th>This term includes fruit juices, squashes, nectars, ready-to-serve beverages, carbonated beverages, synthetic juices, fruit juice concentrates and dry instant drinks.</th>
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<tbody>
<tr>
<td><strong>Dietary fibre</strong></td>
<td>It is that part of plant food which is resistant to digestion in the human beings.</td>
</tr>
<tr>
<td><strong>Fortification</strong></td>
<td>It is defined as a process of adding one or more dietary essentials to food.</td>
</tr>
<tr>
<td><strong>Fruit bars/clothes</strong></td>
<td>They are products prepared by drying fruit pulp and concentrates in the form of sheets.</td>
</tr>
<tr>
<td><strong>Overage</strong></td>
<td>Extra amount of nutrients added during fortification process to compensate for the losses during processing, storage and distribution.</td>
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## 11.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

### Check Your Progress Exercise 1

Your answer should include following points:

1. **Five food groups have been identified by ICMR.**
   - i) cereal, grains and their products, ii) pulses and legumes, iii) fruits and vegetables, iv) milk, meat egg and their products and v) fats and sugars.

2. **It is a process of adding dietary essentials.**
   - Type of nutrient(s) added, their quantity and objective of adding them.

3. **Necessity of fortification**
   - Basic principles of fortification

4. **Enhancement of aesthetic appeal of the diet.**
   - High amounts of vitamins, minerals and fibre.

5. **Capability of vitamin C in removing oxygen**
   - Nutritional improvement

6. **Vitamin C is added at the time of juice extraction to check.**
   - Oxidative discolouration in apple juice.
   - Dry mixing of vitamins to reduce adverse effects of heat on vitamins in pre-mix in instant juice powders.
   - Vitamin premix is added in jelly near the end point but before addition of citric acid.
7. • Effect of heat, pH and oxygen on vitamin C.
• Effect of pH and oxygen on beta-carotene.

11.8 SOME USEFUL BOOKS