

**Post Harvest Operations and Processing of Fruits, Vegetables, Spices and Plantation  
Crop Products**  
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**Lecture 02**  
**Fruits and Vegetables**

In this lecture, the topics on the classification, composition, nutritional value of major fruits and vegetables of India and its consumption pattern (both raw and processed form) will be covered. Also, the importance and health benefits along with the physiochemical, textural, microbiological and other quality characteristics as well as maturity indices of major fruits and vegetables will be discussed.

### Concepts Covered

- Classification, composition, nutritional value of major fruits and vegetables of India and its consumption pattern (raw and processed)
- Importance and health benefits of fruits and vegetables
- Physicochemical, textural, microbiological characteristics
- Quality characteristic & maturity indices



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### Fruits & their Classification

- ❑ The botanic term “fruit” refers to the **seeds and surrounding tissues** of a plant. The foods that are commonly referred to as “fruits” for **culinary purposes** are **pulpy seeded tissues** that have a **sweet** (oranges, apples, pears, blueberries) or **tart** (lemons, limes, cranberries) **taste**.

#### Fruits can be classified based on

- Climatic adaptability



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### Fruits can be classified based on

- Climatic adaptability
- Bearing habit
- Fruit morphology
- Rate of respiration
- Botanical classification



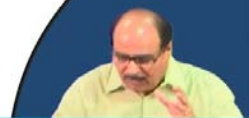
## Fruits and their classification

The botanic term “fruit” refers to the seeds and surrounding tissues of a plant. The foods that are commonly referred to as “fruits” for culinary purposes are pulpy seeded tissues that have a sweet taste (for example oranges, apples, pears, blueberries) or tart taste (like lemons, limes, cranberries).

The fruits can be classified based on the climatic adaptability such as temperate, tropical, and subtropical fruits, bearing habit, fruit morphology, rate of respiration, and botanical classifications.

### Classification based on morphology

Simple Fruits	Modified Berry	Aggregate fruits	Multiple fruit
Derived from single ovary			Derived from separate but closely clustered flowers
<p>↓</p> <p><b>Berry</b></p> <p>wall of the fruit is fleshy</p> <p>Banana   Papaya</p> <p>Sapota</p>	<p><b>Balusta</b> </p> <p><b>Amphisarca</b> </p> <p><b>Pepo</b> </p> <p><b>Pome</b> </p> <p><b>Drupe</b> </p> <p><b>Hesperidium</b> </p> <p><b>Nut</b> </p> <p><b>Capsule</b> </p>	<p>A cluster or aggregation of many ripened ovaries (fruits) produced from a single flower</p> <p>Strawberries   Custard Apple</p>	<p>Jackfruit   Pineapple</p>



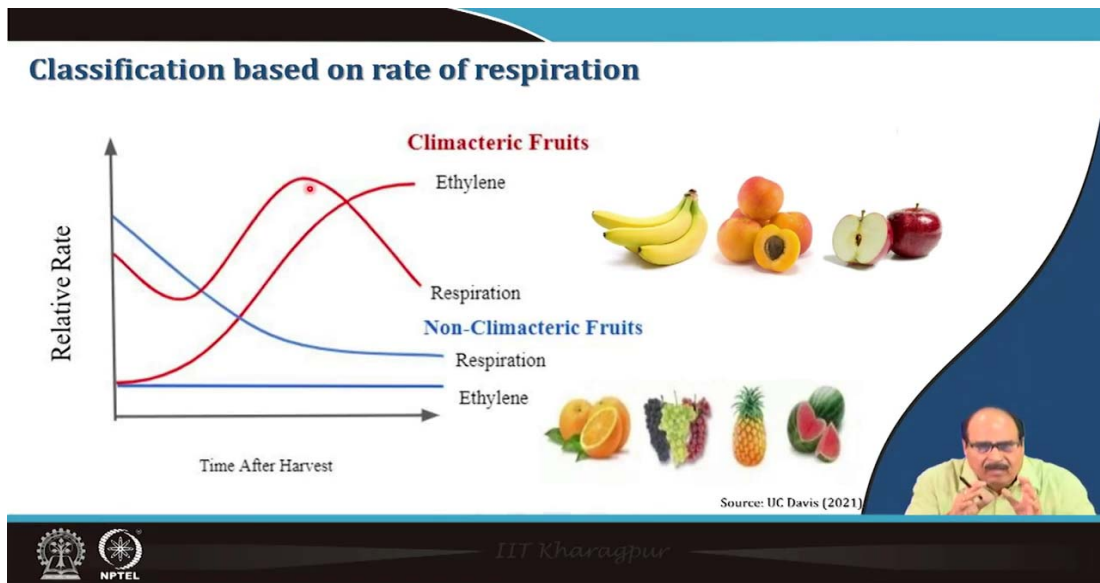
## Classification based on morphology

1. **Simple fruits:** are derived from single ovary (Ex. Berry), where the wall of the fruit is fleshy (Ex. Banana, papaya, and sapota).

**2. Modified berry:** include Balusta, Amphisarca, Pepo (i.e. berry with a hard thick grind), Pome (which has ovary or core surrounded by edible, flussy tissue), Drupe (fleshy fruit with hard inner layer), Hesperidium (berry with a leathery rind and parchment-like partitions), Nut (larger, one seeded fruit with very hard pericarp), and Capsule (where seed pod splits open).

**3. Aggregate fruits:** are a cluster or aggregation of many ripened ovaries which are produced from a single flower (Ex. Strawberries and Custard Apple).

**4. Multiple fruits:** are derived from separate but closely clustered flowers (Ex. Jackfruit and Pineapple).



### Classification based on rate of respiration

Based on the rate of respiration, the fruits are classified into two groups: climacteric and non-climacteric. The fruits such as banana, papaya, apples etc. are come under climacteric fruits where there is a significant increase in the rate of respiration after the ripening stage.

Finally, the fruit respiration comes to its climatic maxima and senescence starts. At the climatic maxima point, the fruit is at its maximum keeping value (or eating value) after that senescence starts and product spoils.

In the case of non-climatic fruits, there is a continuous decrease in both the rate of respiration as well as ethylene production after the harvesting of product.

The vegetables are the edible part of plants which includes stems and stalks like (eg. celery), roots (eg. carrots), tubers (eg. potatoes), bulbs (eg. onions) leaves (eg. spinach, lettuce), flowers (eg. artichokes) and other fruits (eg. cucumber, pumpkins, and tomatoes), seeds (eg. beans, peas). Vegetables are generally less sweet are tart than fruits and are usually consumed as salads cooked side dishes and savory appetizers.

## Vegetables & their Classification

### □ Vegetables are edible plant parts including

- Stems and stalks (celery)
- **Roots (carrots)**
- Tubers (potatoes)
- **Bulbs (onions)**
- Leaves (spinach, lettuce)
- **Flowers (artichokes)**
- Some fruits (cucumbers, pumpkin, tomatoes)
- **Seeds (beans, peas)**



- ✓ Vegetables are less sweet or tart than fruits and are usually consumed as salads, cooked side dishes and savory appetizers.

Source: Penington & Fisher, 2009



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## Composition & Nutritional Value of Fruits & Vegetables

- About **70 - 90%** of the most fruits and vegetables are mainly composed of **water (tomato 96%, cucumber 98%)**.
- Fruits and vegetables are a **major source of macronutrients such as fiber and micronutrients such as minerals and vitamins C, thiamin, riboflavin, B<sub>6</sub>, niacin, folate, A, and E.**
- **Phytochemicals** in fruits and vegetables, such as **polyphenolics, carotenoids, and glucosinolates**, also provide nutritional value.
- Initial nutrient content is affected by cultivar, soil type, production system, and weather conditions during growth.
- **Remaining changes in nutrient composition from harvest to consumption depends on the nutrient, commodity, and the post-harvest handling, storage, and cooking conditions.**



Source: Barret (2007)



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## Composition & Nutritional value of fruits and vegetables

About 70 to 90% of the most fruits and vegetables are mainly composed of water (Ex. Tomato contains 96% and cucumber contains 98% water). Fruits and vegetables are major source of micronutrients such as fiber and micronutrients such as minerals, vitamin C, thiamin, riboflavin, B<sub>6</sub>, niacin, folate, A and E. Phytochemicals in fruits and vegetables, such as polyphenolics, carotenoids, and glucosinolates, also provide their nutritional value. Initial nutrient content is affected by the cultivar, soil type, production system, and weather conditions during the growth. Remaining changes in nutrient composition from harvest to consumption depends upon the nutrient, commodity, and post-harvest handling, storage, and cooking conditions.



## Nutritive value of fruits

- Fruits are important sources of **vitamins and carbohydrates** like fiber and sugar.
- Ripe fruit contains a higher percentage of sugar chiefly in the form of sucrose, fructose and glucose.
- Fruits are poor source of protein and fat.
- Generally fruits are **poor source of iron** except for certain fruits like seethaphal.
- **Mangoes** are the excellent source of **carotenes**. Apart from mango, Indian dates, papaya and oranges also provide  $\beta$ - carotene.
- **Sea buckthorn & Amla** are the richest source of **vitamin C** followed by guava. Citrus fruits are cheap & popular sources of vitamin C.
- Some fruits like **apples, pears, cherries, grapes** and **citrus fruits** contain **flavonoids** that act as **antioxidants**.

Source: IASRI (2011)



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## Nutritive value of fruits

Fruits are important sources of vitamins and carbohydrates like fibers and sugar. Ripe fruits contain a higher percentage of sugars chiefly present in the form of sucrose, fructose and glucose. Fruits are poor sources of protein and fat. Generally, fruits are poor sources of iron except for certain fruits like Seethaphal. Mangoes are the excellent sources of carotenes. Apart from mango, Indian dates, papaya and oranges also provide  $\beta$ -carotene. Sea buckthorn and Amla are the richest sources of vitamin C followed by guava. Citrus fruits are cheap and popular sources of vitamin C. Some fruits like apples, pears, cherries, grapes and citrus fruits contain flavonoids that act as antioxidants.

## Composition of major fruits of India

	Moisture (g/100g)	Energy (kcal)	Protein (g/100g)	Fat (g/100g)	Carbohydrates (g/100g)	Calcium (mg/100g)	Iron (mg/100g)	Carotene (ug/100g)	Vit C (mg/100g)
<b>Banana</b>	70.1	116	1.2	0.3	27.2	17	0.4	78	70
<b>Mango</b>	81.0	74	0.6	0.4	16.9	14	1.3	2743	16
<b>Orange</b>	87.6	48	0.7	0.2	10.9	26	0	1104	30
<b>Papaya</b>	90.8	32	0.6	0.1	7.2	17	0.5	666	57
<b>Guava</b>	81.7	51	0.9	0.3	11.2	10	0.3	0	212



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Source: IASRI (2011)

The table represents the nutritional compositions such as moisture, energy, protein, fat, carbohydrate, calcium, iron, carotene, and vitamin C of some major fruits of India including banana, mango, orange, papaya, guava.

## Nutritive value of vegetables

- Vegetables contribute to the **fibre** content of the **diet**.
- They are fairly **good source of vitamins and minerals**.
- **Green leafy vegetables are good sources of  $\beta$ -carotene, calcium, riboflavin, folic acid, ascorbic acid, iron and vitamin K.**
- Green-leafy vegetables also contain vitamin C and can be used as substitute for fruits if needed. Agathi, drumstick leaves and coriander leaves contribute to vitamin C.
- **Roots and tubers give more calories compared to green-leafy vegetables because they contain more starches.**
- Roots and tubers are fairly good source of vitamin C.
- **Most of the vegetables are poor source of protein and fat.**








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Source: IASRI (2011)

## Nutritive value of vegetables

Vegetables contribute to the fibre content of the diet. They are fairly good source of vitamins and minerals. Green leafy vegetables are good sources of  $\beta$ -carotene, calcium, riboflavin, folic acid, ascorbic acid, iron and vitamin K. Green leafy vegetables also contain vitamin C and can be used as substitute for fruits if needed. Agathi, drumstick leaves and coriander leaves contribute to vitamin C. Roots and tubers give more calories compared to green leafy vegetables because they contain more starches. Roots and tubers are fairly good sources of vitamin C. Most of the vegetables are poor sources of protein and fat.

## Composition of major vegetables of India

	Calories	Total Carbohydrate (g)	Dietary Fiber (g)	Sugars (g)	Vit A (%DV)	Vit C (%DV)	Calcium (%DV)	Iron (%DV)
<b>Potato</b>  148 g	110	26	2	1	0	45	2	6
<b>Onion</b>  148 g	45	11	3	9	0	20	4	4
<b>Tomato</b>  148 g	25	10	2	1	20	40	2	4
<b>Cabbage</b>  83 g	25	5	2	3	0	70	4	2
<b>Cauliflower</b>  99 g	25	5	2	2	0	100	2	2




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Source: FDA (2017)

The table represents the nutritional compositions such as energy values, dietary fiber, sugars, Vitamin A & C, calcium, and iron of some major vegetables of India including potato, onion, tomato, cabbage, and cauliflower.


## Health Benefits of Fruits & Vegetables




**Add flavour and colour to the diet**




**Supply essential micronutrients**




**Maintenance of wide variety of metabolic functions**



**Provide bulk to the diet**




**Provide dietary and crude fibre**


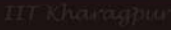


**Provide bioactive for health promotion & disease prevention**

**The benefit of a diet rich in fruits and vegetables is attributed to the complex mixture of phytochemicals strongly associated with the reduced risk of cardiovascular disease, cancer, obesity, diabetes, Alzheimer disease, cataracts and age related functional decline.**

Source: dirhorti.assam.gov.in, Slavin & Lloyd (2012)




















### Health benefits of fruits and vegetables



It is said that “an apple a day keeps doctor away, a banana a day keeps hospital away”. So, these fruits and vegetables are health promoting nutrients including both macronutrients and micronutrients. They add flavor and color to the diet; supply essential micronutrients. Fruits and vegetables maintain a wide variety of metabolic functions in the body and also provide bulk to the diet which aids in excretion processes and improves the digestion. They provide dietary fibers and bioactive for health promotion and disease prevention.

The benefit of a diet rich in fruits and vegetables is attributed to the complex mixture of phytochemicals strongly associated with the reduced risk of cardiovascular diseases, cancer, obesity, diabetes, Alzheimer disease, cataracts and age-related function functional decline of the body.

## Health benefits of selected fruits & vegetables

<div style="margin-bottom: 10px;">  <p><b>Grapefruits</b> Studies suggest that grapefruits (red &amp; pink only) have important antioxidant benefits due to presence of lycopene</p> </div> <div style="margin-bottom: 10px;">  <p><b>Cantaloupes</b> Contain a diverse profile of nutrients like beta-carotene, which could lower the risks for developing asthma</p> </div> <div style="margin-bottom: 10px;">  <p><b>Apples</b> Contain phytonutrients like apple polyphenol, which could help with regulating blood sugar levels</p> </div> <div style="margin-bottom: 10px;">  <p><b>Lemon/Limes</b> Are an excellent source of vitamin C, which is vital to the function of a strong and healthy immune system</p> </div> <div style="margin-bottom: 10px;">  <p><b>Papayas</b> Are a good source of dietary fiber, which has been shown to reduce high cholesterol levels</p> </div> <div style="margin-bottom: 10px;">  <p><b>Pears</b> Are also a good source of fiber, which could help reduce the risks of forming type 2 diabetes and heart diseases</p> </div> <div style="margin-bottom: 10px;">  <p><b>Cranberries</b> Have proanthocyanidin (PAC), which is known to help treat and prevent Urinary Tract Infections</p> </div>	<div style="margin-bottom: 10px;">  <p><b>Cauliflowers</b> Contain glucoraphanin, which could be converted into sulforaphane to provide immune system benefits</p> </div> <div style="margin-bottom: 10px;">  <p><b>Carrots</b> Contain an abundance of vitamin A, which is known for improving your vision and preventing eye diseases</p> </div> <div style="margin-bottom: 10px;">  <p><b>Bok Choy</b> Are a good source of omega-3s, which have been shown to help prevent heart diseases and strokes</p> </div> <div style="margin-bottom: 10px;">  <p><b>Beets</b> Contain a specific type of fiber, which could provide health benefits such as reducing the risk of colon cancer</p> </div> <div style="margin-bottom: 10px;">  <p><b>Kales</b> Contain an unusual mix of carotenoids and flavonoids, which have been shown to reduce the risk of cancer</p> </div> <div style="margin-bottom: 10px;">  <p><b>Swiss Chards</b> Contain syringic acid, which could help people with diabetes by regulating blood sugar levels</p> </div> <div style="margin-bottom: 10px;">  <p><b>Asparagus</b> contains a rich amount of glutathione, a compound that could help break down harmful carcinogens</p> </div>
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## Health benefits of selected fruits and vegetables

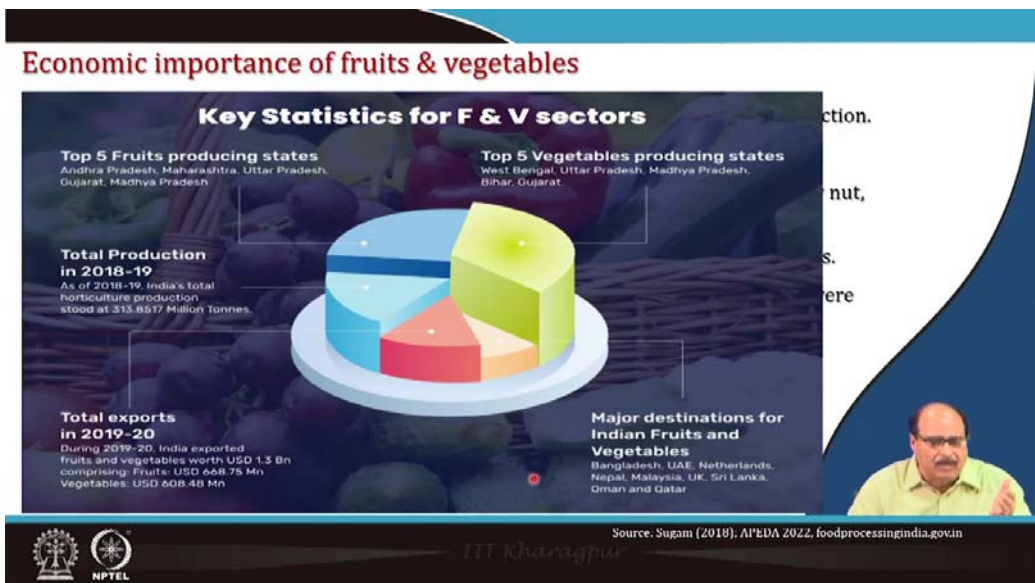
Studies suggest that grapefruits (both red and pink) have important antioxidant benefits due to presence of lycopene. Cantaloupes contain a diverse profile of nutrients like  $\beta$ -carotene, which could lower the risks for developing asthma. Apples contain phytonutrients like apple polyphenol which could help with the regulation of the blood sugar levels. Lemon/limes are excellent source of vitamin C. Papaya are a good source of dietary fiber which has been shown to reduce high cholesterol levels. Pears are a good source of dietary fiber, which could help to reduce type-2 diabetes. Cranberries have proanthocyanidin, which is known to help treat and prevent urinary tract infections. Cauliflower contain glucoraphanin which could be converted into sulforaphane to provide immune system benefits. Carrots contain an abundance of vitamin A which is known for improving the vision and preventing eye diseases. Beets contain a specific type of fiber which could provide health benefits such as reducing the risk of colon cancer. Swiss chards contain syringic acid which could help people with diabetes by regulating blood sugar levels. So, these fruits and vegetables contain variety of health promoting ingredients.

### Economic importance of fruits & vegetables

- In India, fruits and vegetables account for nearly 90% of the total horticulture production.
- India is now the second largest producer of fruits and vegetables in the world
- It is the leader in several horticultural crops, namely mango, banana, papaya, cashew nut, areca nut, potato, and okra.
- India produced 99.07 million tonnes of fruits and 191.77 million tonnes of vegetables.
- The area under cultivation of fruits stood at 6.66 million hectares while vegetables were cultivated at 10.35 million hectares.
- During 2020-21, India exported fruits and vegetables worth Rs. 4,971.22 crores and Rs. 4,969.73 crores, respectively.
- In FY 2019, ~8.31 million tonnes of fruits and vegetables were processed in India, which is expected to reach 16.39 Mn tons by 2024, expanding at a CAGR of ~14.84% during the FY 2020-24

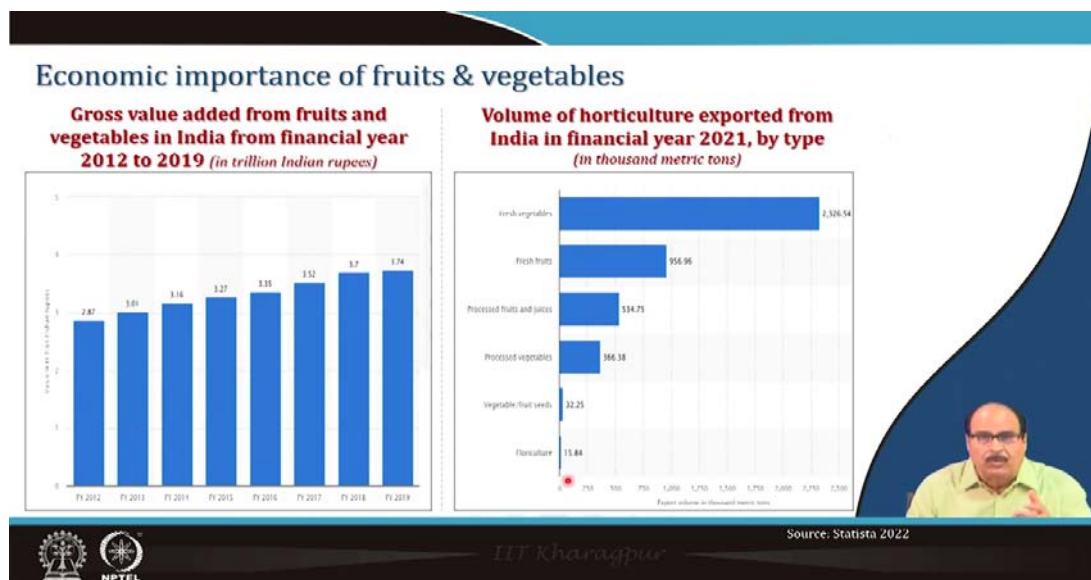






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### Economic importance of fruits and vegetables

The left hand side figure represents the progressive increase in the gross value added from fruits and vegetables in India from the financial year 2012 to 2019. The right hand side figure denotes the volume of horticultural produces exported from India in the financial year 2021 and it can be clearly observed that fresh vegetables positioned first followed by fresh fruits, processed fruits and juices, processed vegetables, vegetable/fruit seeds, and lastly floriculture.

Major Fruits of India							✓ Area in '000 Hectares	✓ Production in '000 MT
Crops	2017-18		2018-19		2019-20			
	Area	Production	Area	Production	Area	Production		
Banana	884	30808	866	30460	877	31779		
Mango	2258	21822	2296	21378	2301	20529		
Citrus Total	1003	12546	1028	13404	1058	14032		
Papaya	138	5989	149	6050	144	6086		
Guava	265	4054	276	4253	290	4359		
Pomegranate	234	2845	25	2915	275	3256		
Grapes	139	2920	140	3041	147	2939		
Watermelon	101	2520	100	2495	109	2922		
Apple	301	2327	308	2316	309	2783		
Jackfruit	185	1830	185	1764	188	1776		

Source: Agriculture statistics 2020

The table represents the area of cultivation (in thousand hectares) and production (in thousand MT) of major fruits of India in the year 2017-18, 2018-19, and 2019-20.

Major Vegetables of India							✓ Area in '000 Hectares	✓ Production in '000 MT
Crops	2017-18		2018-19		2019-20			
	Area	Production	Area	Production	Area	Production		
Potato	2142	51310	2173	50190	2056	48662		
Onion	1285	23262	1220	22819	1431	26148		
Brinjal	730	12801	727	12680	723	12345		
Tomato	789	19759	781	19007	813	21195		
Cabbage	399	9037	400	9127	398	9213		
Cauliflower	453	8668	465	9083	459	8844		
Okra	509	6095	513	6176	534	6371		
Peas	540	5422	552	5562	568	5791		
Tapioca	173	4950	163	4976	173	5582		
Chillies (Green)	309	3592	377	3783	363	4027		

Source: Agriculture statistics 2020


The table represents the area of cultivation (in thousand hectares) and production (in thousand MT) of major vegetables of India in the year 2017-18, 2018-19, and 2019-20.

### Quality characteristics of fruits and vegetables

Quality is defined as the degree of excellence of a particular product or its suitability for a particular use. It includes value attributes such as purity, compositional integrity, size, appearance, taste, convenience of preparation.


Generally, nutritional attributes are considered as fat content, total calories, fibre, sodium, vitamins, minerals, other micro and micro nutrients which contribute to the nutritional quality characteristics of a product.

### Quality Characteristics of Fruits and Vegetables

 Quality is defined as the degree of excellence of a product or its suitability for a particular use.

- Value attributes
- Nutrition attributes
- Food safety attributes
- Package attributes
- Production process attributes


- Purity
- Compositional integrity
- Size
- Appearance
- Taste
- Convenience of preparation



Source: Hussain et al., 2010


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### Quality Characteristics of Fruits and Vegetables

 Quality is defined as the degree of excellence of a product or its suitability for a particular use.

- Value attributes
- Nutrition attributes
- Food safety attributes
- Package attributes
- Production process attributes

- Fat
- Calories
- Fibre
- Sodium
- Vitamins
- Minerals



Source: Hussain et al., 2010

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## Quality Characteristics of Fruits and Vegetables



Quality is defined as the degree of excellence of a product or its suitability for a particular use.

Value attributes

Nutrition attributes

Food safety attributes

Package attributes

Production process attributes

- Food borne pathogens
- Heavy metals
- Pesticide residues
- Food additives
- Naturally occurring toxins



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Source: Hussain et al., 2010

Food safety is an important attribute consisting of food borne pathogens, presence of heavy metals, pesticide residues, food additives, naturally occurring toxins which may lead to health hazards after consumption.

## Quality Characteristics of Fruits and Vegetables



Quality is defined as the degree of excellence of a product or its suitability for a particular use.

Value attributes

Nutrition attributes

Food safety attributes

Package attributes

Production process attributes

- Package materials
- Labelling
- Other information provided



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Source: Hussain et al., 2010

Package attributes include the suitable packaging material, labeling and other information provided on the packet. The production process attributes include genetic modification, environmental impact on the product, pesticide use, and worker safety.



## Quality Characteristics

### Value attributes



#### • Texture

- **Texture** is a key fruit and vegetables quality component when considering consumer acceptability.
- Fruit texture, and particularly **flesh firmness**, is used as an **important maturity index**, in combination with other quality parameters.
- Vegetables such as cucumbers, peppers, and potatoes, should be as firm as possible.
- The **surface** of fruits and melons should be **smooth and firm**.
- Texture can be determined by using **texture analyzer** or firmness of fruit is estimated by **penetrometer**.

#### • Morphology

- It involves the **physical form** of the fruit or vegetable, such as **size, weight or curvature**.
- Instruments such as **scales, sizing machines** and **tape measures** are used to make **non-destructive measurements**.



Source: umd.edu, C.A. Blecher & Sons, do Nascimento Nunes, M. C. (2009).



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## Value attributes

Texture is considered to be the very important quality attributes. Texture is a key fruit and vegetable quality component when considering consumer acceptability. Fruit texture, and particularly flesh firmness, is used as an important maturity index, in combination with other quality parameters. Vegetables such as cucumbers, peppers, and potatoes, should be as firm as possible. The surface of fruits and melons should be smooth and firm. Texture can be determined by using texture analyzer or firmness of fruit is estimated by penetrometer.

Morphology involves the physical form of the fruit or vegetable such as size, weight or curvature. Instruments such as scales, sizing machines and tape measures are used to make non-destructive measurements of morphology.

#### • Smell

- Important attribute especially in fruits such as citrus.
- It gives information about the **aromatic and volatile substances** present in both the skin and the pulp.
- Objective way to measure it through **gas chromatography combined with mass spectrometry, E-Nose**.

#### • Visual quality

- It is one of the **most important factors that determine the market value** of fresh fruits and vegetables.
- **Color is one the primary indicators of maturity or ripeness.**
- Colour is a **key indicator on how fresh the produce** is, alongside other visual cues.
- Coloration of fruits and vegetables should be even without marks and spots.
- It can be measured using **colorimeter, tintometer** or **Hunter colour difference meter**.



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Smell is an important value attribute especially in the fruits such as citrus. It gives information about the aromatic and volatile substances present in both the skin and pulp.

Objective way to measure it is through gas chromatography combined with mass spectrophotometry and electronic nose (E-Nose).

The visual quality is one of the most important factor that determines the market value of fresh fruits and vegetables. Color is one of the primary indicators of maturity or ripeness. It is a key indicator on how fresh the produce is alongside other visual cues. Coloration of fresh fruits and vegetables should be even without any marks or without any marks and spots. The color can be measured by using calorimeter, tintometer or Hunter color difference meter.

**Internal quality characteristics**

**Soluble solids**

- It is measured by **refractometer** and allows to know the amount of sugar present in a sample, as the **brix scale**.
- It also **indicates the maturity of the fruit** and indicates the best time to harvest it.

**Acidity**

- It is obtained through the juice of the fruit with a **pH electrode**.
- In addition to the level of **acidity** present in the product being known, it allows to know what possibility exists of **proliferation of microbes**, since this factor directly affects the ease with which external agents can enter.

### Internal quality characteristics

The determination of internal quality characteristics require instruments such as soluble solids of food products are measured by refractometer and allows to know the amount of sugar present in a sample, as the brix scale. It also indicates the maturity of the fruit and indicates the best time to harvest a fruit. Acidity is obtained through the juice of the fruit with a pH electrode. In addition to the level of acidity present in the product being known, it allows to know what possibility exists for proliferation of microbes. Because the growth of the microorganisms is directly related to the pH or acidity of a product. This factor directly affects the ease with which external agents can enter. So, acidity from that point of view becomes an important consideration.

## Maturity Indices of Fruits and Vegetables

### □ Maturity

#### Harvest maturity

- The stage, which will allow fruits / vegetables at its peak condition when it reaches to the consumers and develop acceptable flavour or appearance and having adequate shelf life.

#### Commercial maturity

- Stage of development when plant parts possess the necessary characteristics preferred by consumers.

#### Physiological maturity

- Stage in the development of the fruits and vegetables when maximum growth and maturation has occurred.

#### Horticulture maturity

- Developmental stage of the fruit on the tree, which will result in a satisfactory product after harvest.



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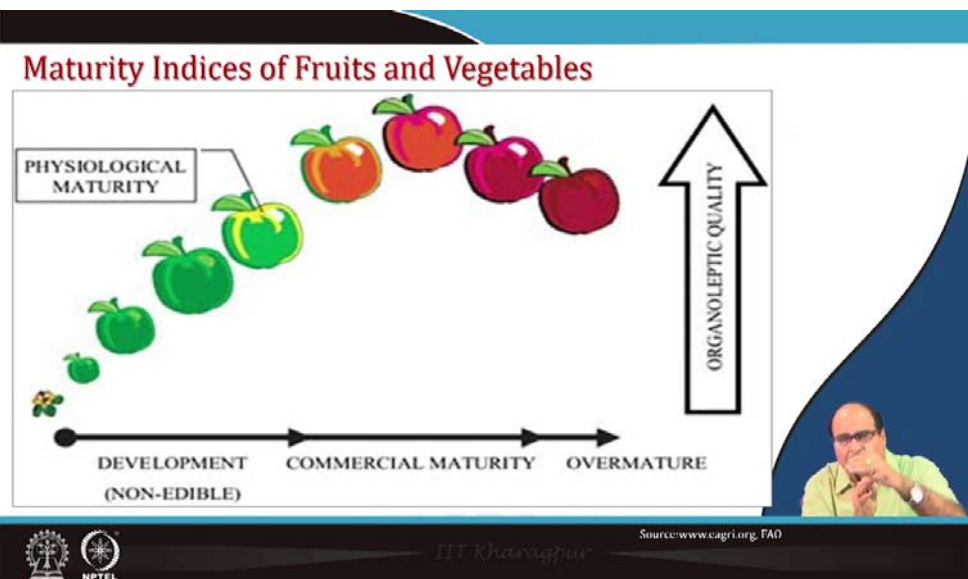
Source: www.cagri.org, FAO



## Maturity indices of fruits and vegetables

### Maturity

The various maturity indices are harvest maturity, commercial maturity, physiological maturity, and horticulture maturity. **Harvest maturity** is the stage which will allow fruits/vegetables are at their peak condition when it reaches to the consumers and develop acceptable flavor or appearance and having adequate shelf life. The **commercial maturity** is the stage of development when plant parts possess the necessary characteristics which is preferred by the consumer that is it has a good eating quality. The fruit should be good in taste, flavor, and color. So, commercial maturity should have a good market value. **Physiological maturity** is the stage in the development of the fruits and vegetables when maximum growth and maturation has occurred. **Horticulture maturity** is the developmental stage of the fruit on the tree, which will result in a satisfactory product after harvest.



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Source: www.cagri.org, FAO



The figure represents different maturity indices of tomato. The physiological maturity is the developmental stage in which size of the fruit increases and green color develops but during this stage the fruit is generally non-edible. In the commercial maturity, red color develops and after this stage, product becomes over mature and quality gets reduced.

**Maturity indices**

- Maturity indices are indications by which the maturity is judged.
- It is necessary or essential to pick up the fruits or vegetables at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life.


**Various indexes**

**Subjective**

- ✓ Qualitative
- ✓ Use the senses (color, size, shape, sound, firmness, juice content etc.)

**Objective**

- ✓ Quantitative
- ✓ Are measurable indices (TSS, TA, Starch content, oil content, firmness, dry matter, days after full bloom, heat degree day, respiration and ethylene production, production of volatiles etc.)



Source: Amit (2018)

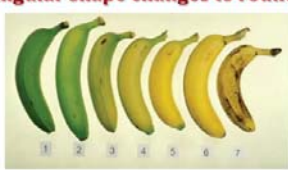
## Maturity indices

Maturity indices are indications by which the maturity is judged. It is necessary or essential to pick up the fruit or vegetable at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life. The indices may be subjective like qualitative which uses the sensors (color, size, shape, sound, firmness, juice content etc.) or objective like quantitative which are measurable indices (TSS, total acidity, starch content, oil content, firmness, dry mater, days after full bloom, heat degree day, respiration and ethylene production, production of volatiles etc.).



**Maturity indices for selected fruits**

Fruits	Maturity indices
Citrus, Papaya, Pineapple, Grapes, Mango, Strawberry	Peel colour
Mango, Apple	Pulp colour
Citrus, Apple, Pear	Size
Banana, Pineapple, Litchi, Mango	Shape
Banana	Drying of plant parts
Melon, Mango	Surface characteristics
Musk melon, Grape, Mango (Tapka stage)	Ease of separation from plants
Watermelon	Tapping
Jackfruit	Aroma
Mango, Pineapple, Guava	Specific gravity
Melons, Apple, Pear	Firmness
Melon, Grapes	Sugars

**Angular shape changes to round**



**Loss of Green Color**

Source: Hathi et al. (2020)



The table shows different maturity indices for selected fruits such as citrus, papaya, pineapple, grapes, mango, strawberry etc. As shown in the figure, the banana undergoes different stages of maturity stages in which the angular shape is progressively changing into round shape as well as the color changes from green to yellow. Similar change in color was observed in various maturity indices of strawberry.

### Maturity indices for selected vegetables

Vegetable	Maturity indices
Tomato	Seeds slipping when fruit is cut, or green colour turning pink
Egg plant, Bitter gourd, Slicing cucumber	Desirable size reached but still tender
Water melon	Dull hollow sound when thumped
Musk melon	Easily separated from vine with a slight twist leaving clean cavity (full slip stage)
Snake gourd	Desirable size reached and thumbnail can still penetrate flesh readily
Cowpea, Snap bean, Sweet pea, Winged bean	Well filled pods that snap readily
Lima bean and Pigeon pea	Well filled pods that are beginning to lose their greenness
Okra	Desirable size reached and the tips of which can be snapped readily

Source: Hathi et al. (2020). [www.freshpoint.com](http://www.freshpoint.com)

The table shows different maturity indices for selected vegetables such as tomato, egg-plant, bitter gourd, water melon, musk melon, snake gourd etc. As shown in figure, the color change is a major maturity index of tomato as presented in stage 1 to 6.

### Summary


- ✓ Fruits are the ripened ovary and classified based on their climatic adaptability, morphology and rate of respiration.
- ✓ Vegetables are the edible portion of the plant which might include stem, leaf, roots, flowers, fruits and seeds.
- ✓ Fruits and vegetables are the primary source of micronutrients, fiber in the diet. They also provide phytochemical and bioactive compounds with health benefits and disease prevention properties.
- ✓ Fruits and vegetables accounts for 90% of the total horticulture production, their value is expected to grow at a CAGR of ~14.84% during the FY 2020-24.
- ✓ Appearance, morphology, texture, flavour, TSS and total acidity remain as the major harvest indices and determines the quality of the fruits and vegetables.

In summary, fruits are the ripened ovary and classified based on their climatic adaptability, morphology and rate of respiration. Vegetables are the edible portion of the plant which might include stem, leaf, roots, flowers, fruits and seeds. Fruits and vegetables are the primary source of micronutrients, fiber in the diet. They also provide phytochemical and bioactive compounds with health benefits and disease prevention properties. Fruits and vegetables accounts for 90% of the total horticulture production, their value is expected to

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These are the references for further study lecture. Thank you.