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

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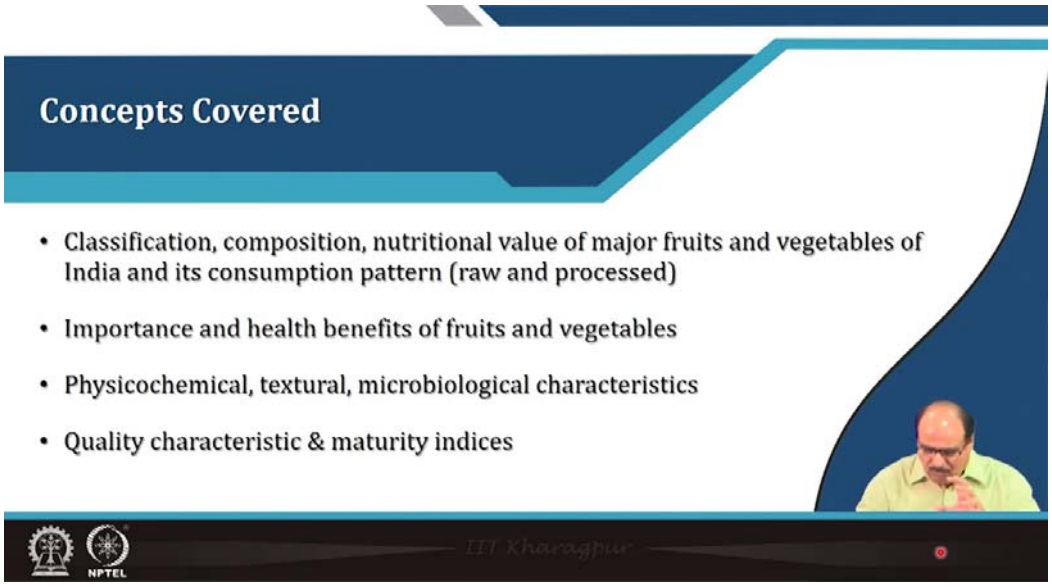
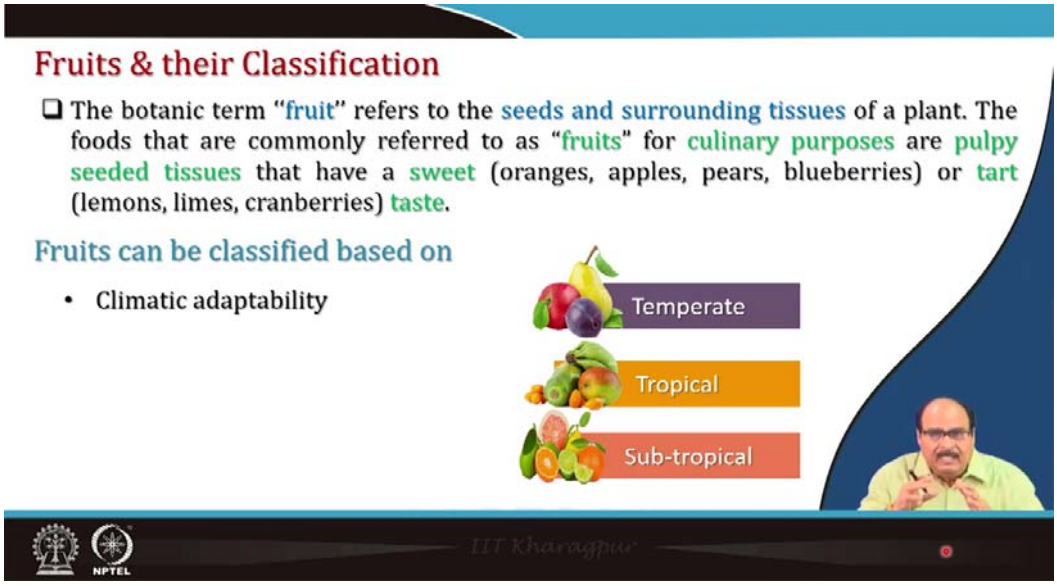
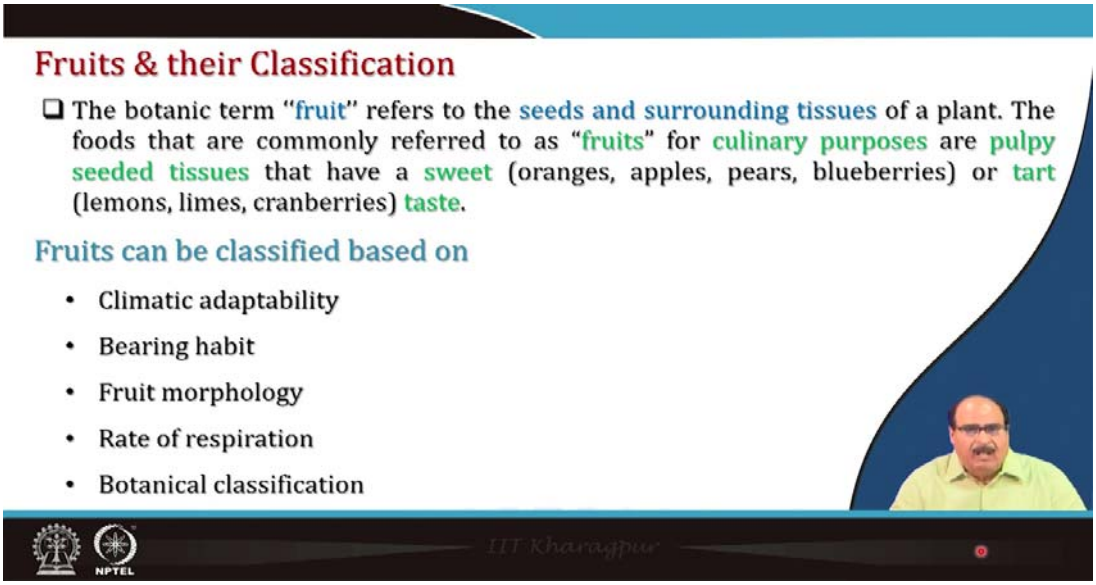
Lecture 02
Fruits and Vegetables

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.



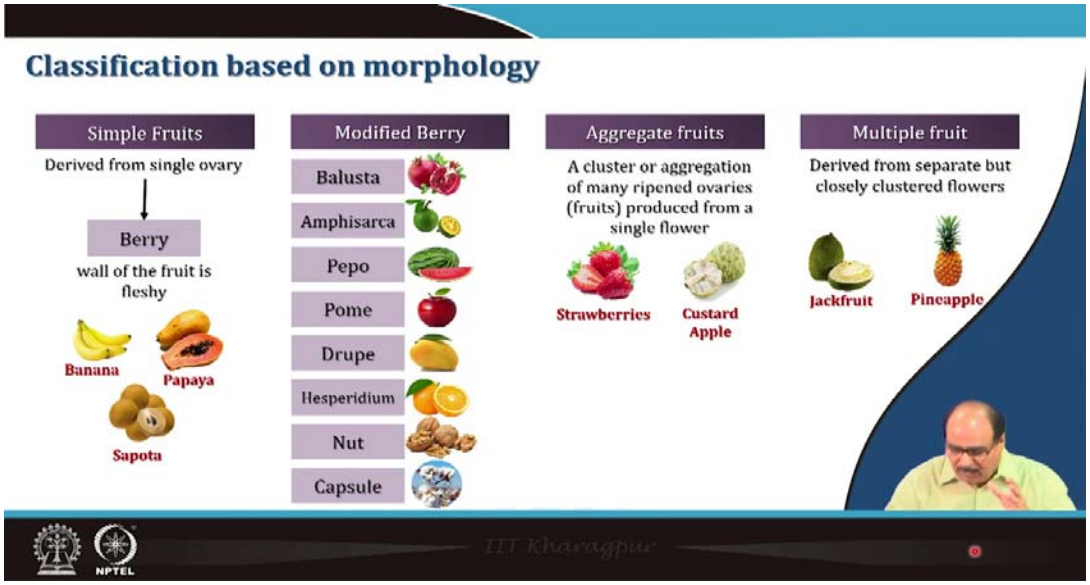




Fruits and their classification

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.



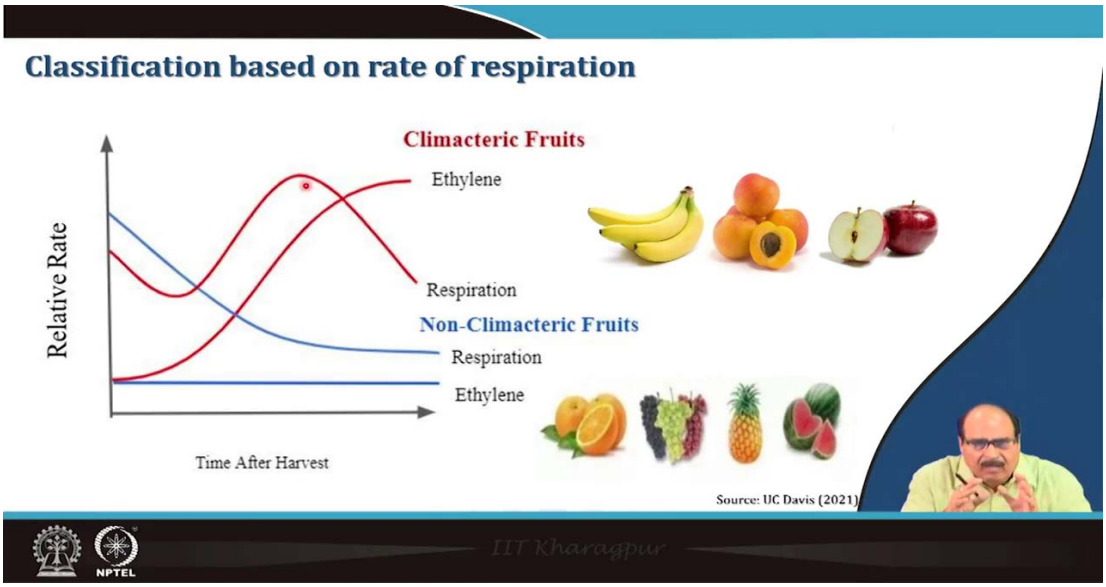
Classification based on morphology

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), Hersperidium (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).



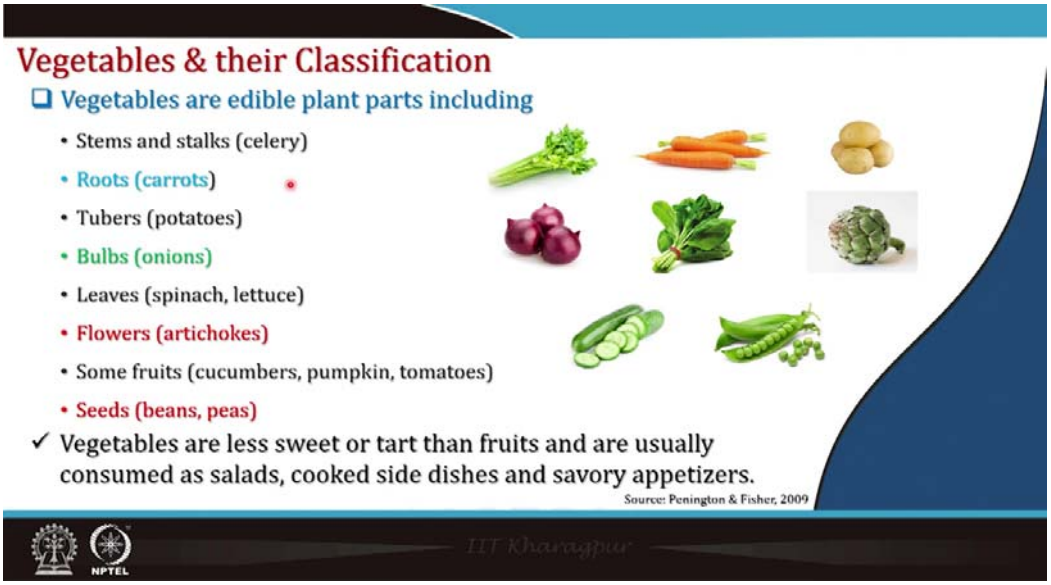
Classification based on rate of respiration

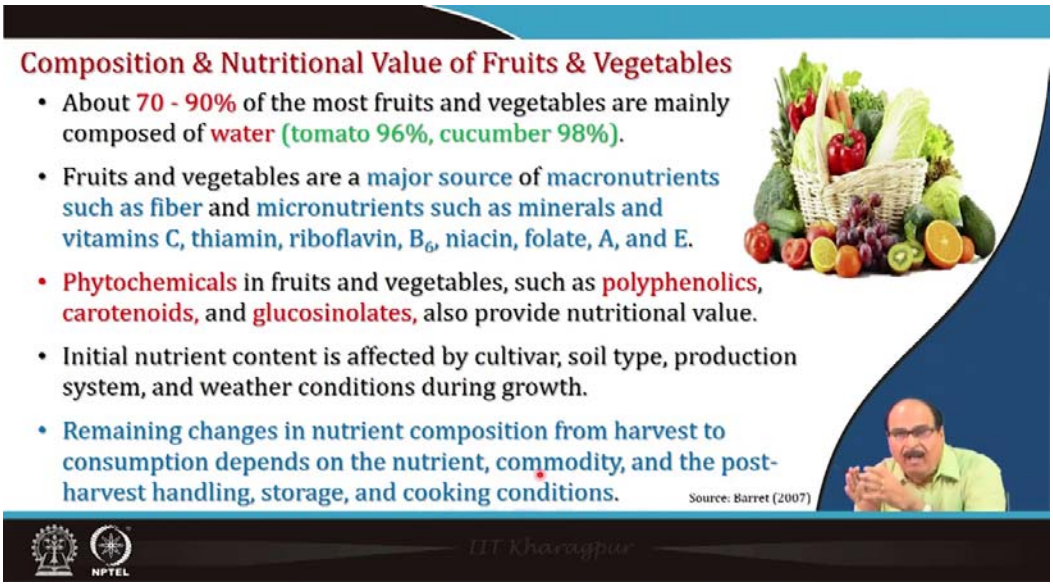
Based on the rate of respiration, the fruits are classified into two groups: climacteric and non-climacteric. The fruits such as banana, papaya, apples etc. are come under climacteric fruits where there is a significant increase in the rate of respiration after the ripening stage.

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.

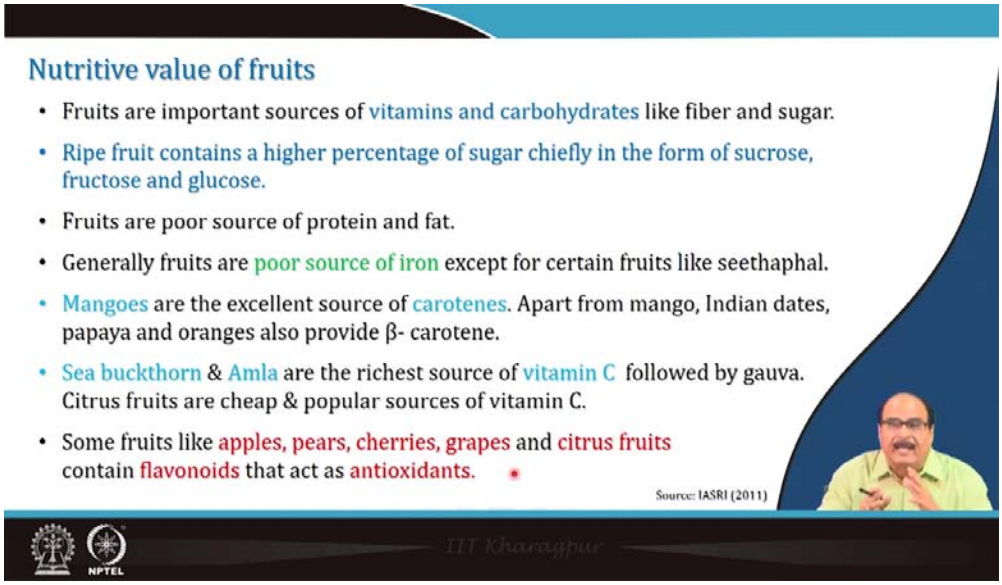
The vegetables are the edible part of plants which includes stems and stalks like (eg. celery), roots (eg. carrots), tubers (eg. potatoes), bulbs (eg. onions) leaves (eg. spinach, lettuce), flowers (eg. artichokes) and other fruits (eg. cucumber, pumpkins, and tomatoes), seeds (eg. beans, peas). Vegetables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





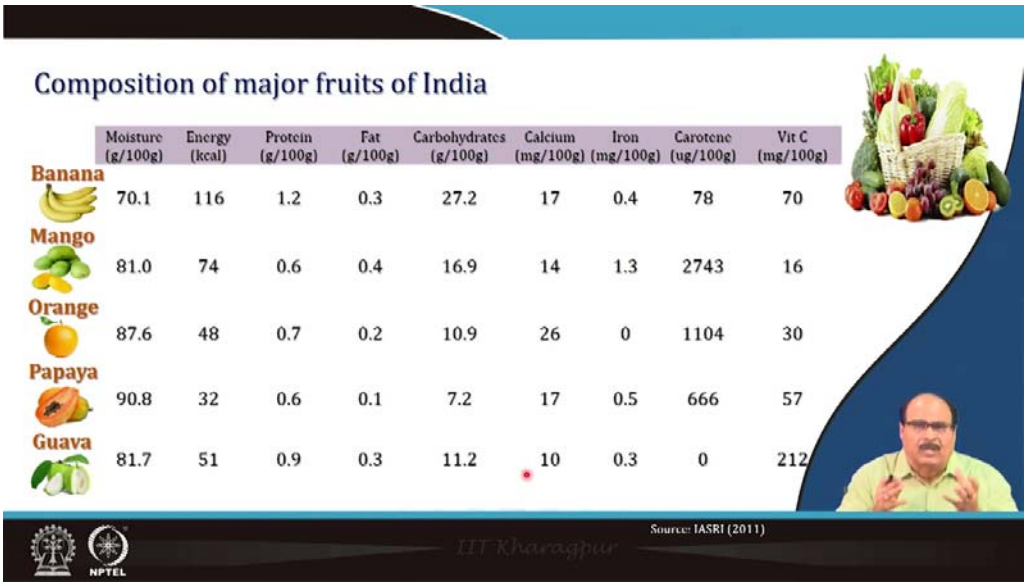
Composition & Nutritional value of fruits and vegetables

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_6, 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.



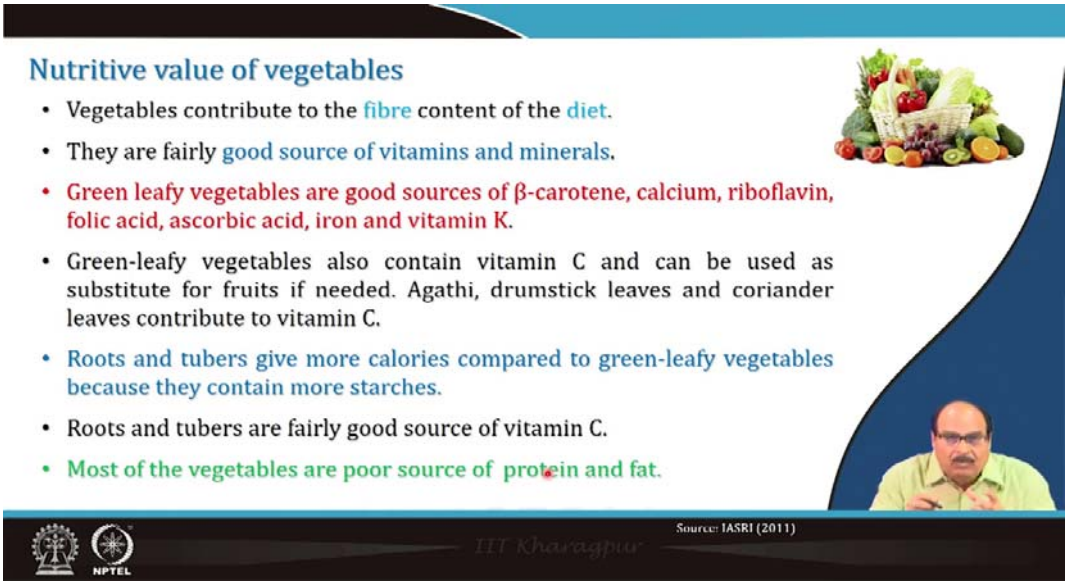
Nutritive value of fruits

Fruits are important sources of vitamins and carbohydrates like 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 β-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.



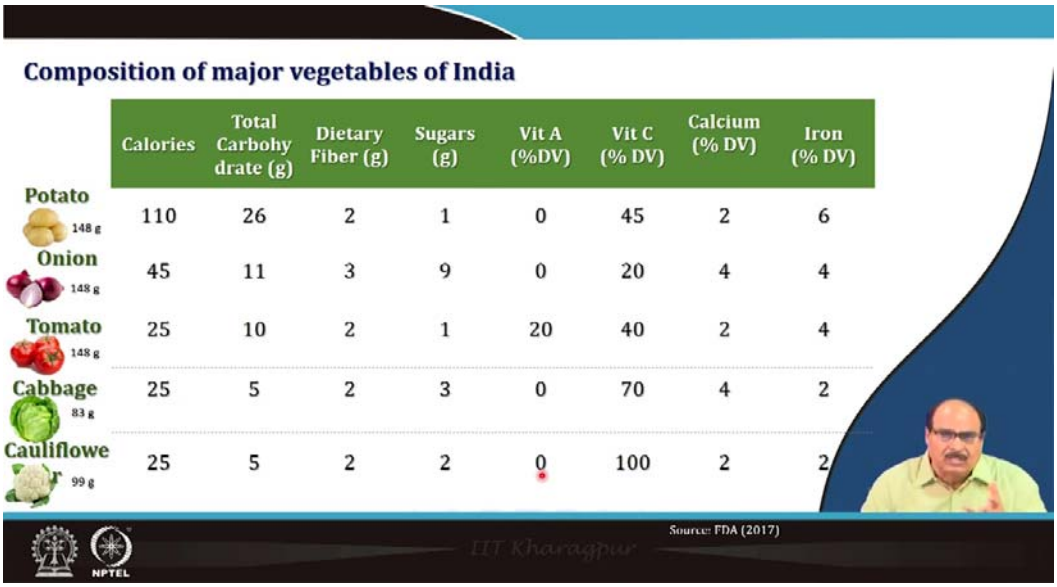
	Moisture (g/100g)	Energy (kcal)	Protein (g/100g)	Fat (g/100g)	Carbohydrates (g/100g)	Calcium (mg/100g)	Iron (mg/100g)	Carotene (ug/100g)	Vit C (mg/100g)
Banana	70.1	116	1.2	0.3	27.2	17	0.4	78	70
Mango	81.0	74	0.6	0.4	16.9	14	1.3	2743	16
Orange	87.6	48	0.7	0.2	10.9	26	0	1104	30
Papaya	90.8	32	0.6	0.1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

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.



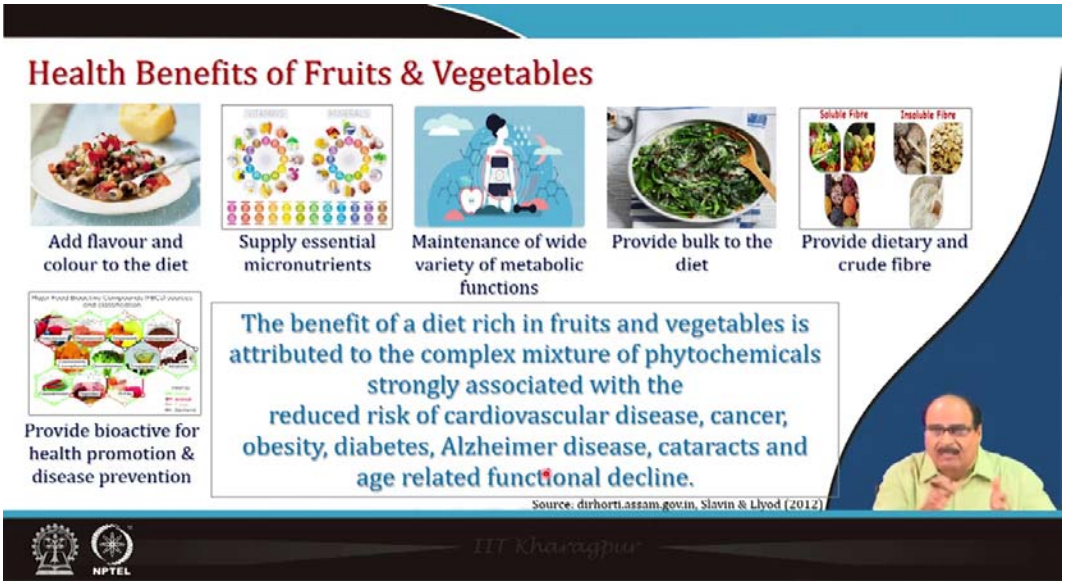
Nutritive value of vegetables

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 β-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.



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

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.



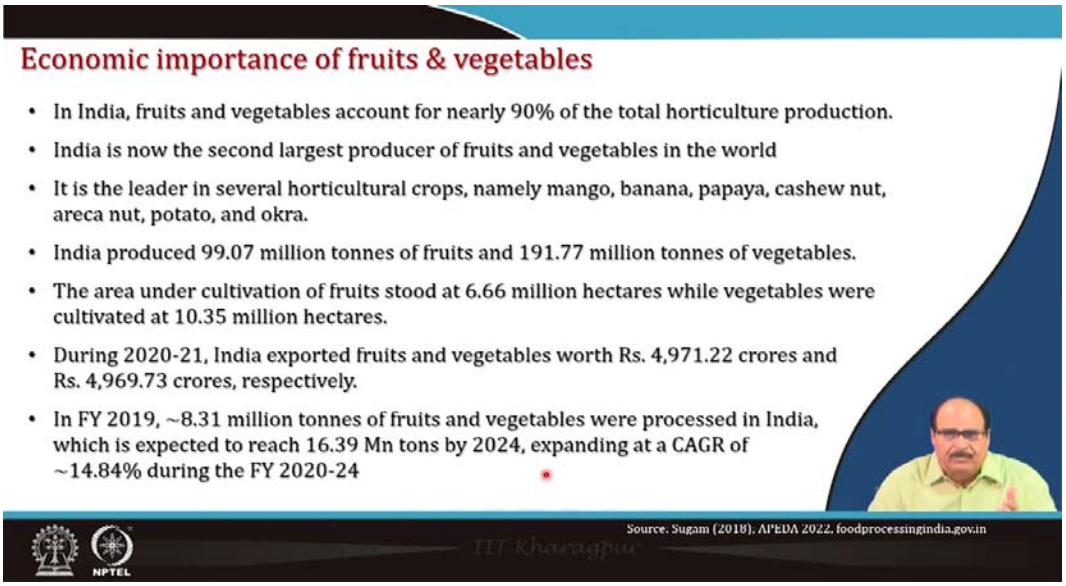
Health benefits of fruits and vegetables

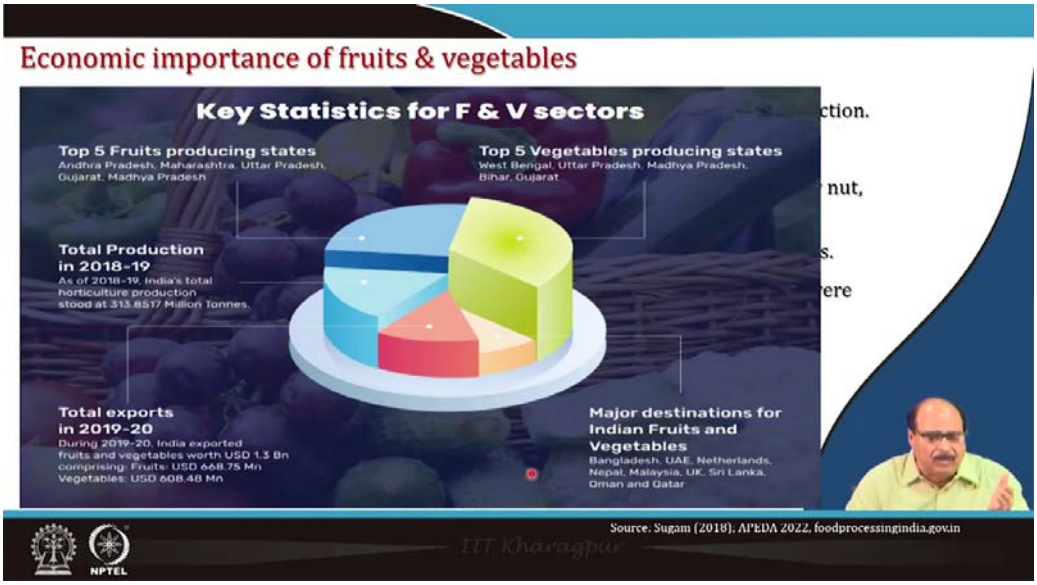
It is said that "an apple a day keeps doctor away, a banana a day keeps hospital away". So, these fruits and vegetables are health promoting nutrients including both macronutrients and micronutrients. They add flavor and color to the diet; supply essential micronutrients. Fruits and vegetables maintain 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 and vegetables

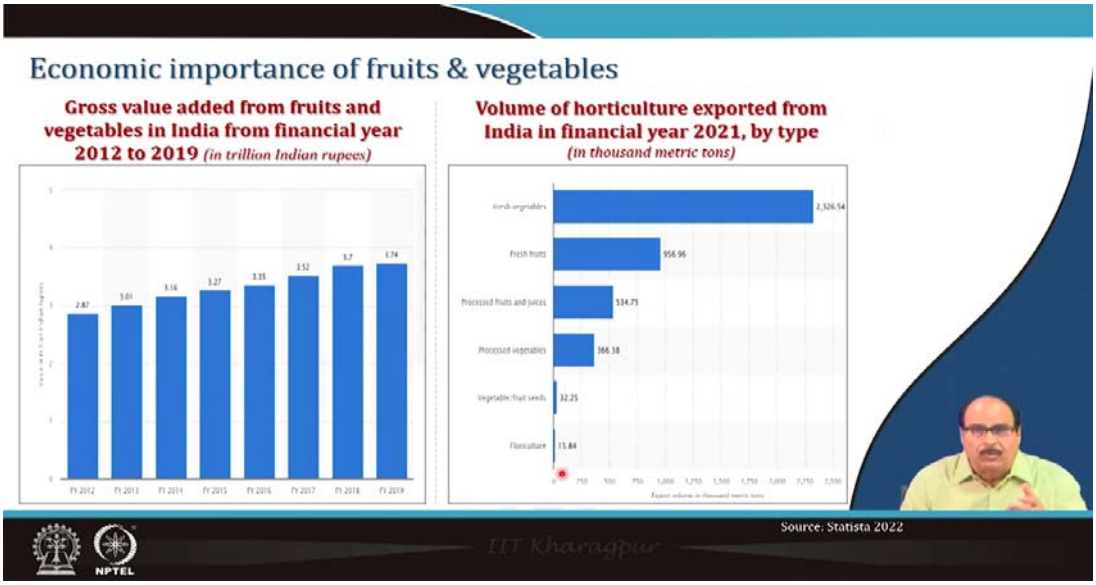
Studies suggest that grapefruits (both red and pink) have important antioxidant benefits due to presence of lycopene. Cantaloupes contain a diverse profile of nutrients like β-carotene, which could lower the risks for developing asthma. Apples contain phytonutrients like apple polyphenol which could 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.





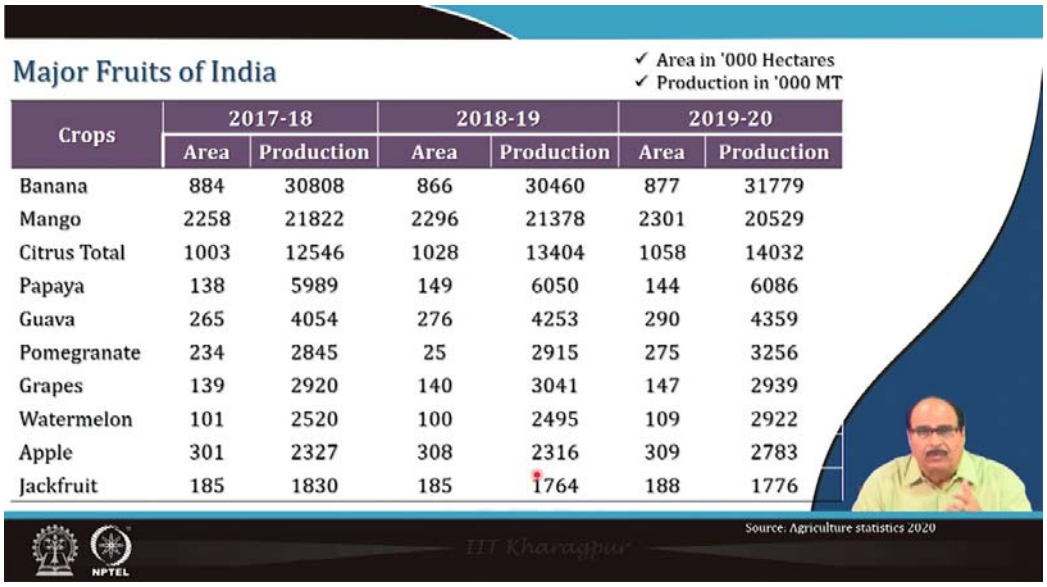
Economic importance of fruits and vegetables

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.



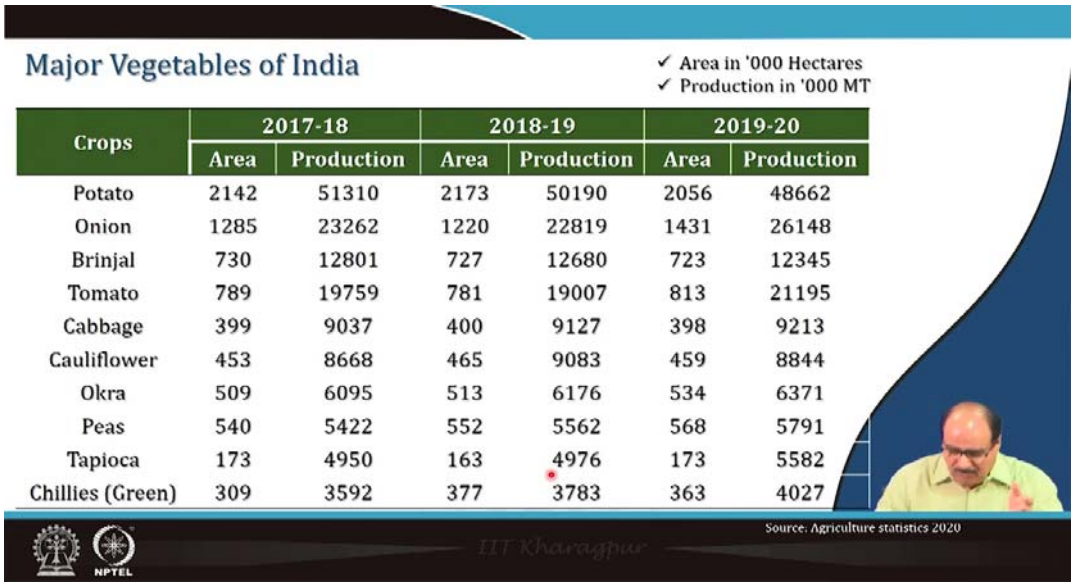
Economic importance of fruits and vegetables

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.



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

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.



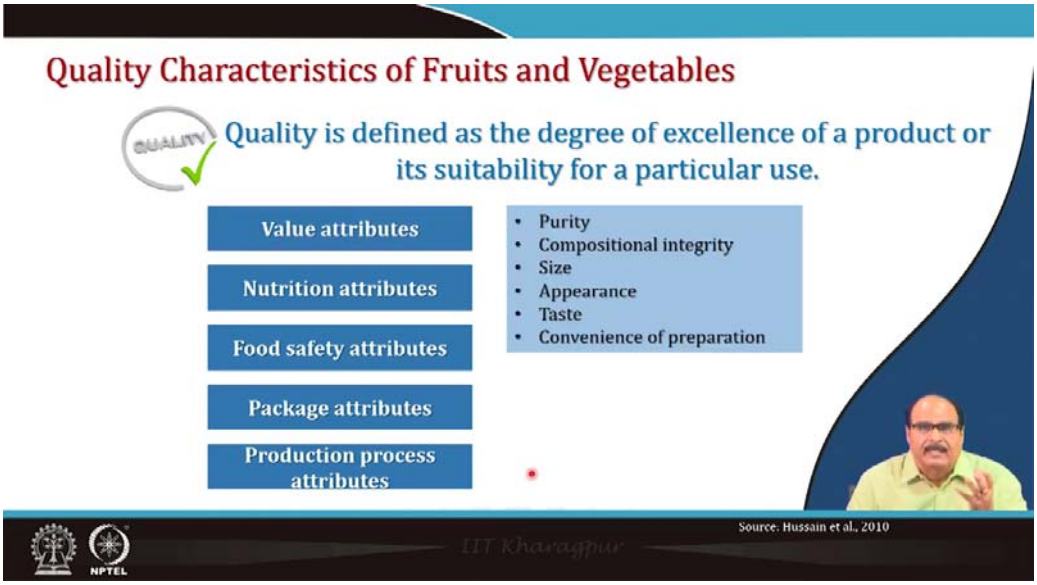
Crops	2017-18		2018-19		2019-20	
	Area	Production	Area	Production	Area	Production
Potato	2142	51310	2173	50190	2056	48662
Onion	1285	23262	1220	22819	1431	26148
Brinjal	730	12801	727	12680	723	12345
Tomato	789	19759	781	19007	813	21195
Cabbage	399	9037	400	9127	398	9213
Cauliflower	453	8668	465	9083	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

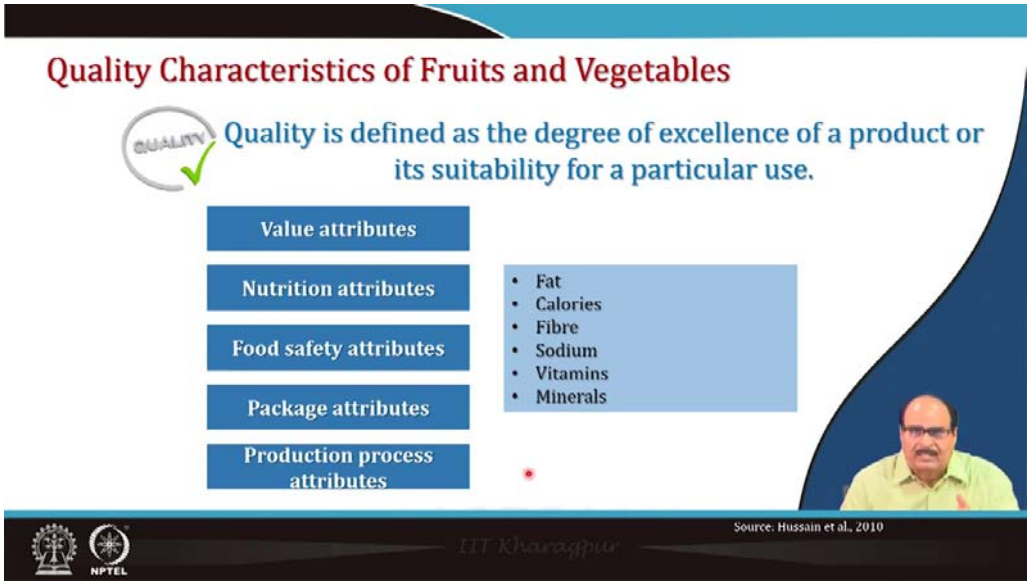
The table represents the area of cultivation (in thousand hectares) and production (in thousand MT) of major vegetables of India in the year 2017-18, 2018-19, and 2019-20.

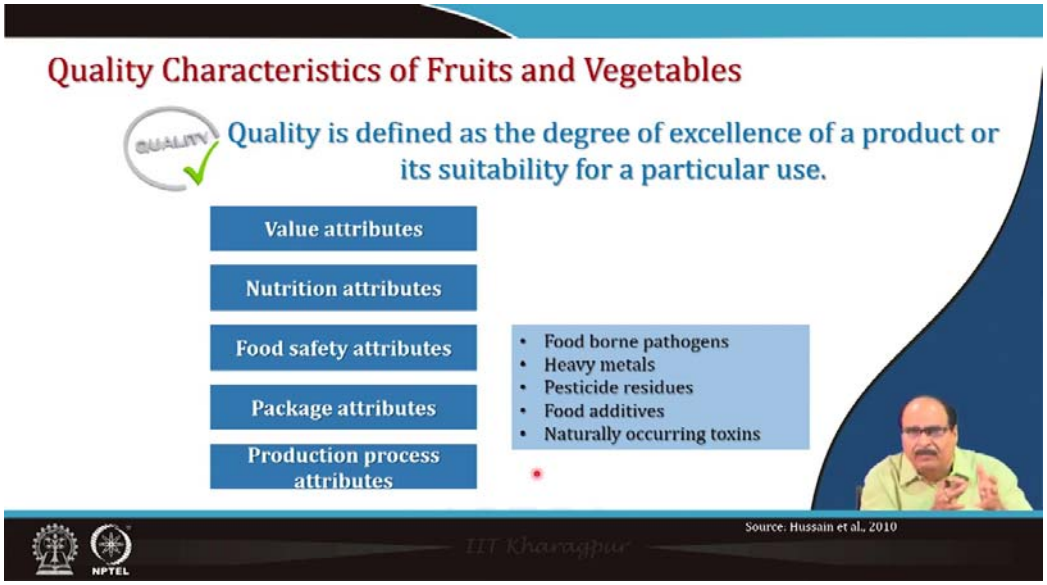
Quality characteristics of fruits and vegetables

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.

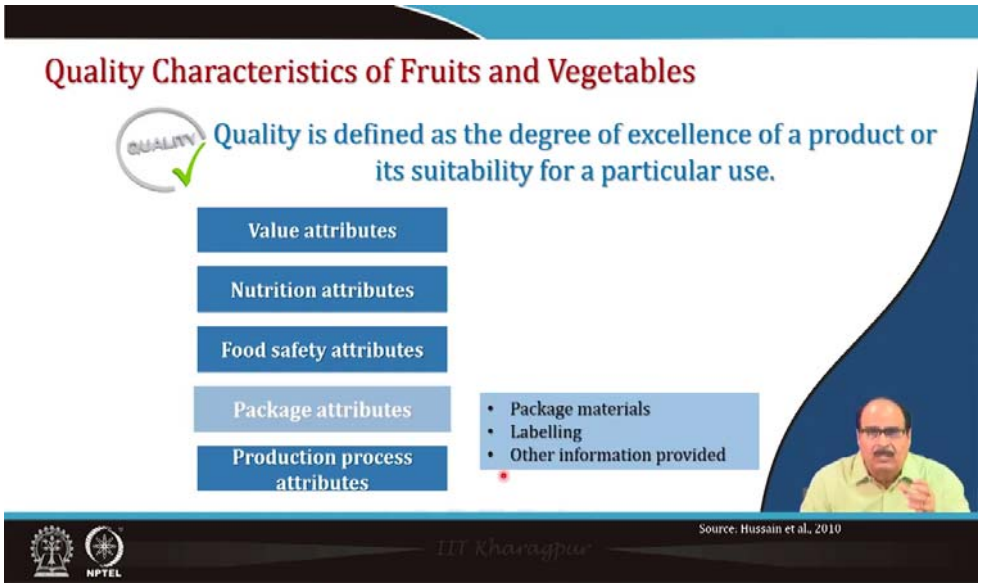
Generally, nutritional attributes are considered as fat content, total calories, fibre, sodium, vitamins, minerals, other micro and micro nutrients which contribute to the nutritional quality characteristics of a product.



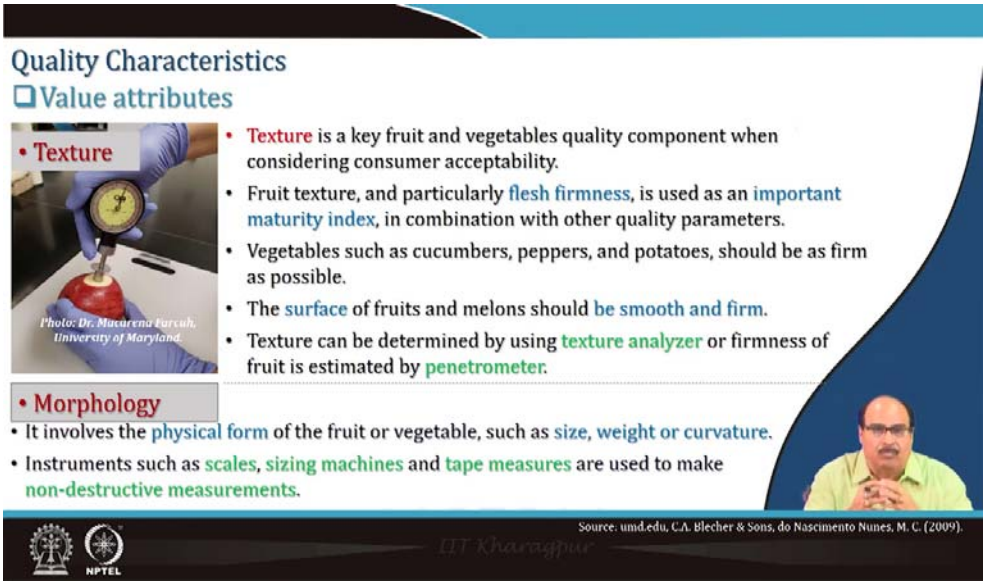




Food safety is an important attribute consisting of food borne pathogens, presence of heavy metals, pesticide residues, food additives, naturally occurring toxins which may lead to health hazards after consumption.



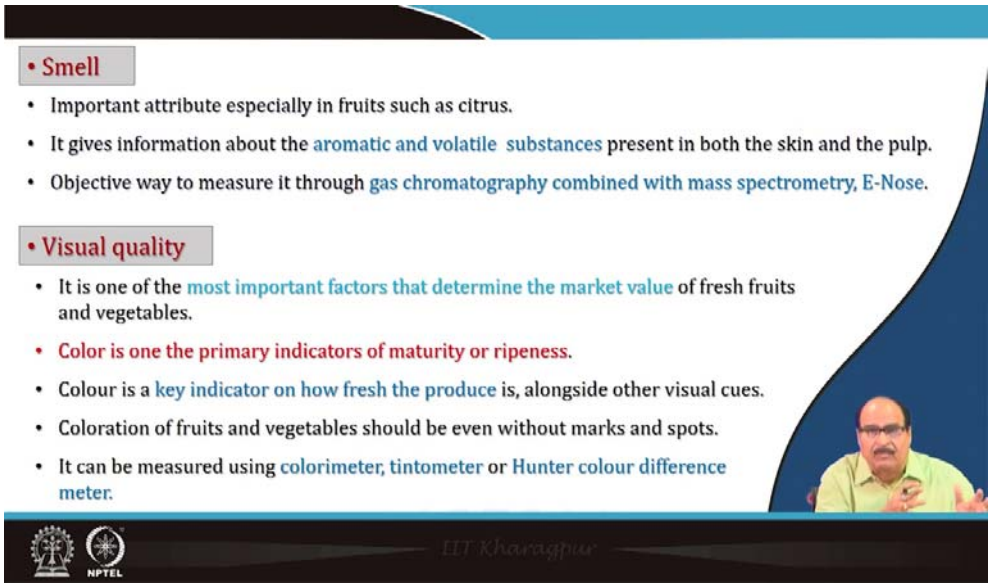
Package attributes include the suitable packaging material, labeling and other information provided on the packet. The production process attributes include genetic modification, environmental impact on the product, pesticide use, and worker safety.



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.

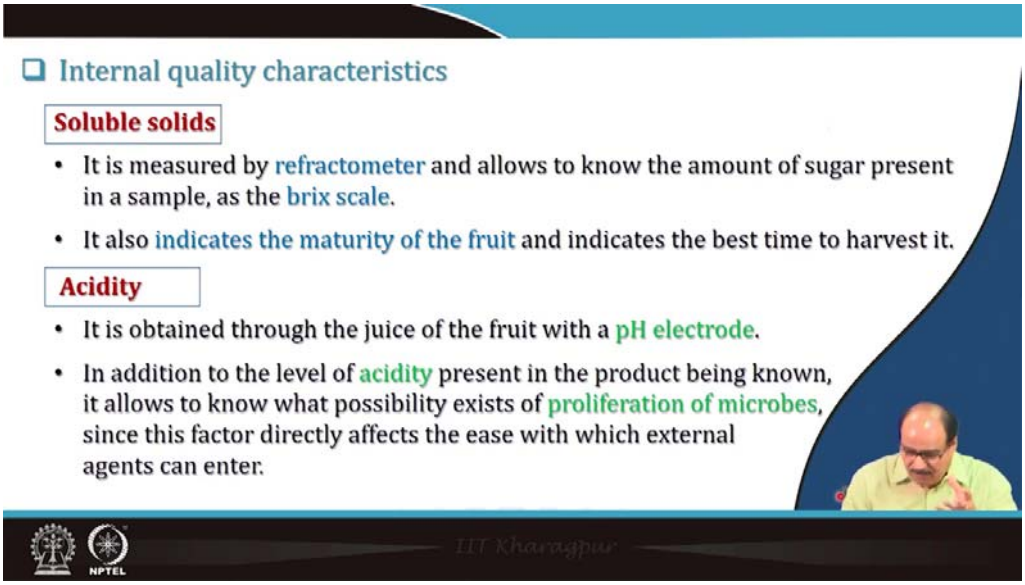
Morphology involves the physical form of the fruit or vegetable such as size, weight or curvature. Instruments such as scales, sizing machines and tape measures are used to make non-destructive measurements of morphology.



Smell 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.

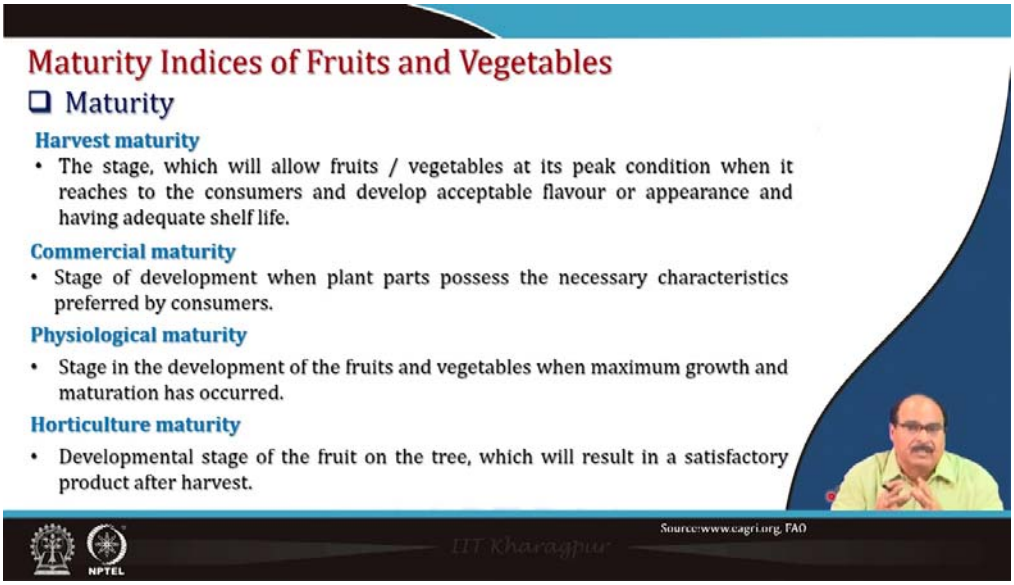
Objective way to measure it is through gas chromatography combined with mass spectrophotometry and electronic nose (E-Nose).

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

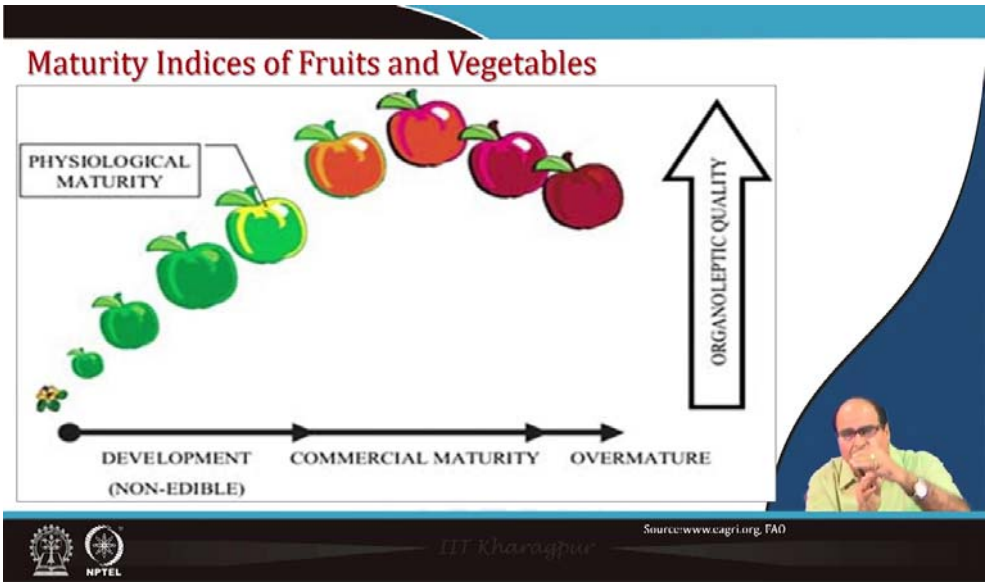
The determination of internal quality characteristics require instruments such as soluble solids of food products are measured by refractometer and allows to know the amount of sugar present in a sample, as the brix scale. It also indicates the maturity of the fruit and indicates the best time to harvest 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.



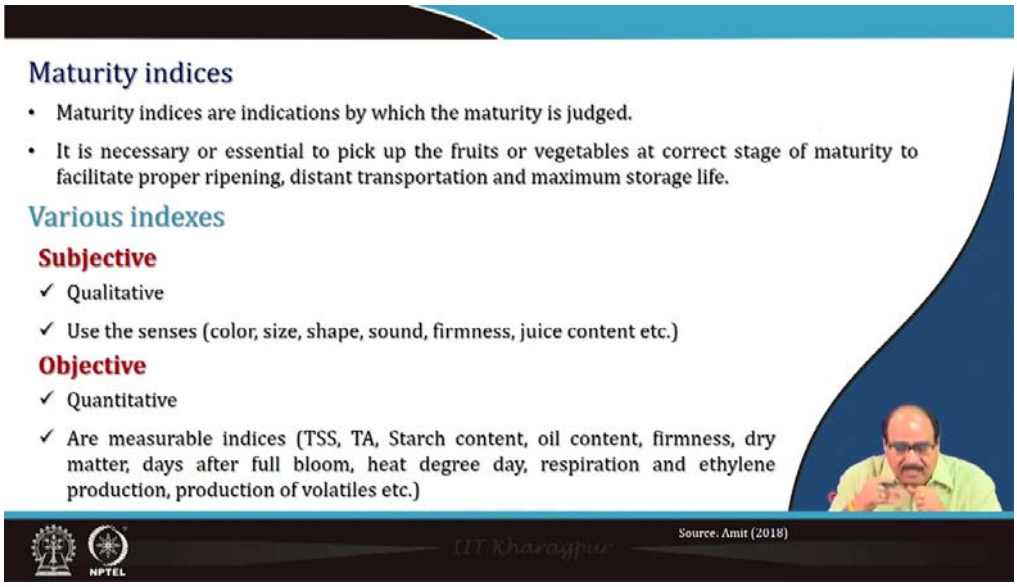
Maturity indices of fruits and vegetables

Maturity

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.

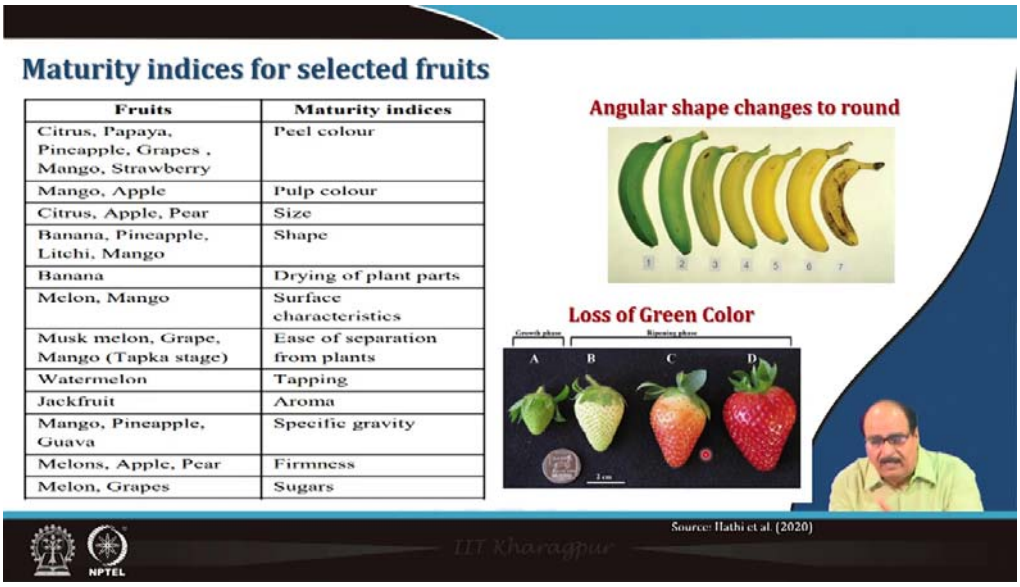


The figure represents different maturity indices of tomato. The physiological maturity is the developmental stage in which size of the fruit increases and green color develops but during this stage the fruit is generally non-edible. In the commercial maturity, red color develops and after this stage,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

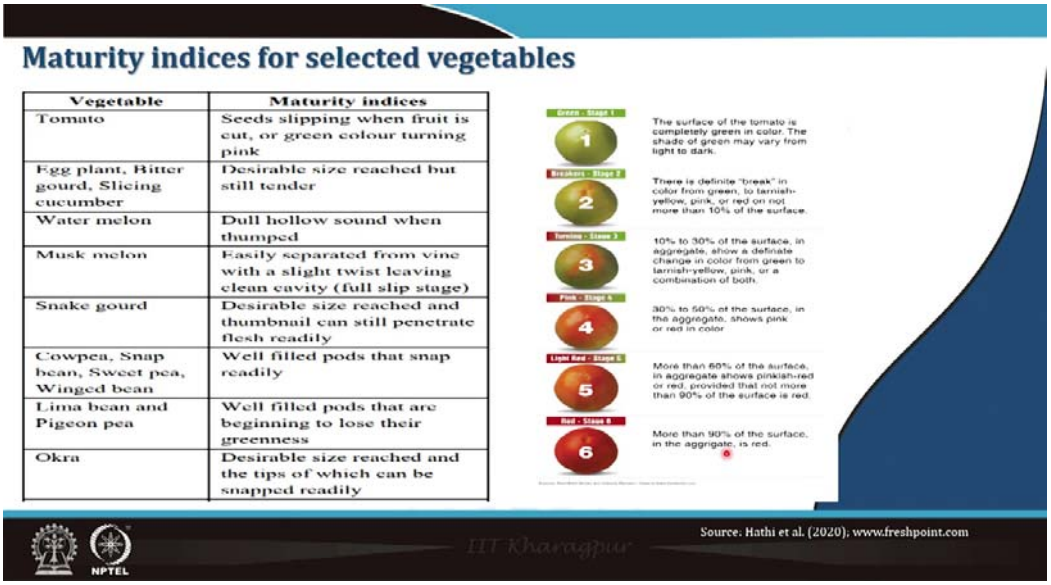


Maturity indices

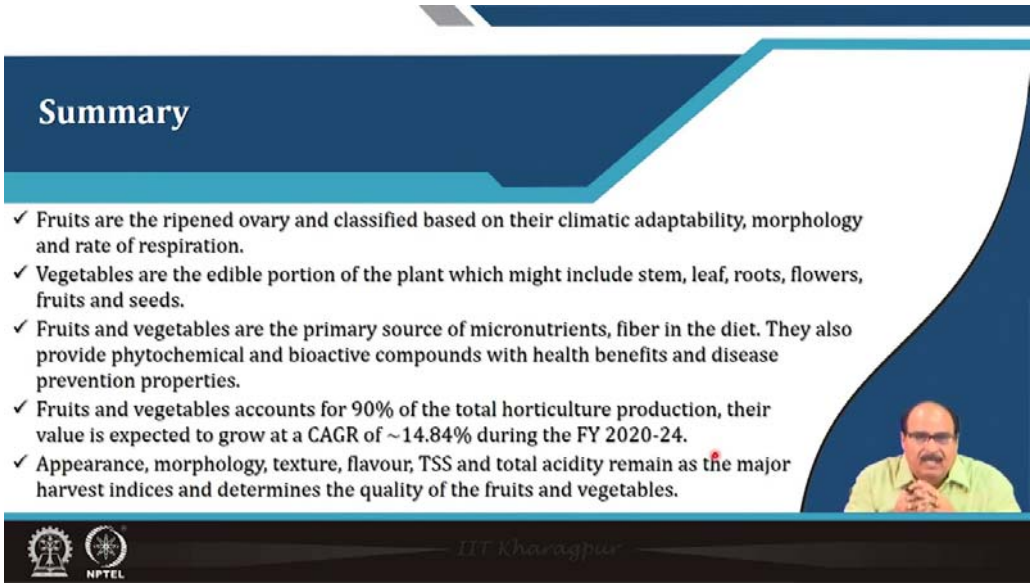
Maturity indices are indications by which the maturity is judged. It is necessary or essential to pick up the fruit or vegetable at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life. The indices may be subjective like qualitative which uses the sensors (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.).



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.



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.



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

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.

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