E-ISSN: 2663-1067
P-ISSN: 2663-1075
IJHFS 2021; 3(1): 46-50
Received: 29-11-2020
Accepted: 30-01-2021

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Impact of temperature and relative humidity in quality and shelf life of mango fruit

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Abstract
The quality of mango is affected by environmental factors, but only a few are the basic limiting factors. Temperature and relative humidity are serious problems under field conditions in harvesting, table and processing mango. In addition, these two basic factors affect quality of mango crop by influencing its physiological processes such as photosynthesis, respiration and other related aspects of the crop activities. This paper review is done for summarizing those factors, affecting mango environment in our country. Successful optimizing of the key factors (temperature and relative humidity) has been achieved with a range of selection of suitable growing seasons including proper environment. Temperature affects the growth and development of mango by denaturing of the activities of enzymes and light also affects the growth and all process by reducing the photosynthetic ability of mango crop.

Keywords: mango, temperature, relative humidity, quality, shelf life

1. Introduction
1.1 Background and Justification
Mango (*Mangifera indica* L.) is one of the most significant tropical fruits in the world and ranked 5th in total world production among the main fruit crops (FAO, 2004) [6]. It has high content of vitamin A and C. It also provides a certain amount of other vitamins and minerals such as riboflavin, niacin, calcium, phosphorus and iron (Jiménez, 2004). Asia continent particularly India are being the leading producer in Global production of mango. Nigeria still occupies the 8th position in the world ranking of mango producing countries as at 2002, even if there is a lack of encouragement as to large scale production of tropical fruits (Sulaimon and Salua, 2007). Fruits and vegetables, including mango are considered very perishable food as a result of their high moisture content (Simal *et al*., 1994) [17]. Accordingly, they exhibit relatively high metabolic activity compared with other plant-derived foods like seeds. This metabolic activity remains after harvesting, thus making most fruits very perishable commodities (Atungulu *et al*., 2004) [1]. Consequently, post-harvest excess moisture content of mango must be minimized to A level acceptable for marketing, storage and processing. Drying is defined as a process of moisture loss as a result of simultaneous heat and mass transfer (Ertekin and Yaldiz, 2004) [5].

Deliberately it's managed to scale back water to the extent at which microbial spoilage and deterioration reactions are greatly diminished (Akpinar and Bicer, 2004). Though there are many ways in which drying can be achieved, but the choice of method depends on the material and the sanitary level required. In tropical and sub-tropical countries sun drying is rampant; the issues include intrusion by animal and pest. This invariably reduces the ultimate quality of the merchandise hence the event of convective dryer is being canvassed for. The affection of drying behavior of mango for optimum and efficient dryer design is expected due to the knowledge of how drying air temperature and slice thickness. Dried mango contain phenol, this phenolic compound has powerful antioxidant and anticancer abilities. It can be eaten as snack or as ingredient in bakery and confectionery products. Several works have been done on drying characteristics of agricultural products.

Time of drying is important in countries where energy cost is high. Although Goyal *et al*. (2006) [7] carried out the thin-layer drying kinetics of fresh mango slice and El-Amin *et al*. (2008) [4] investigated drying kinetics and color change of mango slices are affected by drying temperature and time but none of them put the thickness of the mango slices into consideration with respect to time. Over the last decade, world-wide increase in fresh mango trade has been observed thanks to the advancements in post-harvest handling technology improvements in logistics and communication.

Importance of the study is that Mango are tropical/sub-tropical fruit with a highly significant economic importance. Preferable quality attributes include freedom from external damages such as bruises, latex or sap injury and decay, uniform weight, color, aroma, firmness (with little give away, not soft), shape and size. The fruit has high content of antioxidants and recommended to be involved in the daily diet due to its health benefits such as reduced risk of cardiac disease, anti-cancer, and anti-viral activities. There are so many practices in order to maintain of mango fruit quality during the availability chain encompassing adequate orchard management practices, harvesting practices, packing operation, post-harvest treatments, temperature management, transportation and storage conditions, and ripening at destination.

1.2 Objective
To review the Impact of Temperature and Relative Humidity on Quality and shelf life of Mango fruit

2. Literature Review
2.1. Origin and distribution of mango
The mango originated, within the foothills of the Himalayas of the southern Asia (eastern India, Burma, and therefore the Andaman Islands) bordering the Bay of Bengal, dating back to 4000 BC, where it still grows wild within the hills of Assam and adjacent areas. The earliest mention of mango is found in ancient Sanskrit scriptures dating back to 4000 BC. Mangifera indica, means 'the great fruit bearer'. Historical records and palaeo- botanical evidences provide ample proof about its origin in the Indo-Burma-Malay region. On the idea of presence of maximum number of allied species growing in Malaysia, some workers are cause believe that Malaysian region is that the original home of mango. But Vavilov (1926) [19] supported that mango is originated in 1259 Journal of Pharmacognosy and Phytochemistry Indo-Burma region. Mukherjee (1949b) concluded that occurrence of untamed sort of mango and its allied species and presence of various cultivated and wild varieties in India were a number of the major reasons in favour of mango having originated in Indo-Burma region. The mango is a member of the Anacardiaceae family which includes poison ivy, cashews, and pistachios. It is also referred to as manga, mangga, mangot, mangou, and mangue in other parts of the planet . The mango comes in over 50 varieties, ranging in color from greenish, yellowish, to reddish, often tinged with purple, pink, orange-yellow, or red. Buddhist monks are believed to have taken the mango on voyages to Malaya and eastern Asia during the 4th and 5th Centuries BC. The mango is taken into account to be a sacred fruit within the region because it's said that the Lord Buddha himself meditated under a mango as a result of which he found tranquility and repose during a mango orchard. According to Fa-Hien and Sung-Yun the Lord Buddha was presented with a mango orchard by Amradarika in 500 BC as an area for meditation. The peripatetic Buddhist monks were the primary to spill the beans and initiate the trade of the mango fruit some 400-500 centuries BC. A mango is found within the friezes on the Stupa of Bharut which dates back about 100 BC. The soldiers of Alexandra the good had gone across orchard in Indus Valley. It is speculated that the traders and monks from India introduced superior elections of mango into South-east Asia. The mango is referred within the travelogues of ancient travelers, namely, Hüan Tsang (632-645 AD), ibn Haukul (902-968 AD), and Ibn Batuta (1325-1345 AD). The Chinese traveler Hüan Tsang, during his visit to India (632 - 645 AD) brought the mango to China.

According to a German born botanist, Georg Eberhard Rumphius, in his Het Amboinsche kruidboek or Herbarium Amboinense (1741), the mango was introduced into certain islands of the Indonesia archipelago within recent times; however, the mango was in cultivation in Java as early as early as 900-1100 AD, when the temple at Borobudur was built and faced with carvings of the Lord Buddha in contemplation under a mango According to Candolle (1904) [3] it's impossible to doubt that the mango may be a native of the south of Asia or of the Malay Archipelago. Several investigations are administered on more scientific lines on the origin of the cultivated plants. Vavilov's (1926) [19] work on the genetic variation within the staple crop plants of the planet and therefore the location of the centers of these variations is that the greatest, from which he suggested the 'Indo-Burma' region because the center of origin of the mango. This problem has been further investigated and conclusions are derived by an analysis of the phytogeographical data phylogenetic taxonomy of all the species included within the Mangifera. The Mangifera of the Anacardiaceae and therefore the Sapindales is restricted to the tropical Asia.

2.2. Nutritional Benefits of mango
Mango is a low-calorie fruit that is high in fiber, and is a great source of vitamins A and C, and good for digestion. It also contains folate, B6, iron and a touch calcium, zinc and vitamin E. Mango are an honest source of antioxidants, containing certain phytochemicals like Gallotannins and Mangifera which are studied for his or her health benefits. Just 80g of mango (2 x 2 inch slices) counts together of your five-a-day. This one portion will provide 53 calories, 11g of naturally-occurring sugar and just over 2g of fiber.

As studies show that people who ate mango saw a significant improvement in their constipation symptoms, in part due to the fiber content but potentially from other mango-specific compounds, too. Interestingly, the leaves of the mango are studied and offer potential antidiarrheal activity because of its plant extracts. The mango phytochemicals have also been studied for his or her gastro protective effects, offering both anti-inflammatory and antioxidant properties to the gastrointestinal system, and should even help reduce inflammation in conditions like ulcerative colitis.

Mango contain good levels of both vitamins A and C. Vitamin C is involved within the formation of collagen the protein that gives the skin's elasticity. Vitamin C is one among the foremost important antioxidants, playing a protective role against environmental damage; a deficiency of vitamin C can affect wound healing and increase fine lines and wrinkles. Our hair also requires vitamin C both for collagen production and also to assist with the absorption of iron – a crucial mineral needed for hair growth.

All cells need vitamin A for growth, including the skin and hair, and some studies recommend that it may provide potential protective effects contrary to the signs of ageing. One of vitamin A's key roles in hair and skin health is its involvement within the production of sebum, the oily substance that moisturizes both our skin and scalp. One of the phytonutrients in mango provided heart protective benefits including minimized inflammation. Eating a balanced and varied diet that has five portions of vegetables and fruit, like mango, can help to stay your heart healthy.

2.3. Impact of increase respiration rate on shelf life mango fruit

Respiration occurs when glucose (sugar produced during photosynthesis) combines with oxygen to supply useable cellular energy. This energy is employed to fuel growth and every one of the traditional cellular functions. Carbon dioxide and water are the end product of respiration. Respiration occurs altogether living cells, including leaves and roots. Since respiration doesn't require light energy, it is often conducted in the dark or during the day. However, respiration does require oxygen which may be problematic for roots which are overwatered or in soils with poor drainage. If roots are inundated for long periods of your time, they can't take up oxygen and convert glucose to take care of cell metabolic processes. Waterlogging and excessive irrigation consequently can deprive roots of oxygen, kill root tissue, damage trees, and reduce yield.

2.4. Effect of Concentration of CO_2 on Shelf Life of Mango Fruit

The general CA recommendation for storing mangoes is in an environment containing 5 kPa O_2 and 5 kPa CO_2 (Kader, 1994) [9], however some cultivars may have low tolerance to high levels of CO2 and problems with O_2 levels lower than 2% (Bender and Brecht, 2000). Nakasone and Paull (1998) reported that the shelf-life of Mango extended up to 20 days when store at 12 °C, and 5 kPa O_2 and 5 kPa CO_2, whereas the onset of off-flavors and skin discoloration occurred in environments with 1 kPa O_2 and/or CO_2 levels above 15 kPa. The wide differences in the results can be ascribed to the differences in maturity stages, temperatures and cultivation practices.

Generally, physiological disorders present when mangoes stored in CA, especially with CO_2 levels higher than 25 kPa. 'Tommy Atkins' mangoes produced more ethanol when stored in CA containing 50 kPa and 70 kPa CO_2, and therefore the rate of respiration was more intense when CO_2 levels were above 45 kPa (Bender and Brecht, 2000). The production of volatile compound responsible for the mango aroma was also affected in CO2 levels (> 6 kPa), and it was totally compromised in 'Kensington Pride' mangoes that were stored for up to 35 days in CA containing 6 kPa O_2 and 2 kPa CO2 (Lalel *et al*. 2003). As for the antioxidant phytochemicals, predicament treatment (46 °C per 75 min) and CA storage (3 kPa O_2 and 10 kPa CO_2) didn't adversely change the nutritional profile of 'Tommy Atkins' mangoes (Kim *et al*., 2009) [11].

Hare and Prassad (1993) showed that the response of mangoes to CA is not always positive, in some cultivars, there is only a short increase in shelf life and in others, the shelf life can be extended for up to 1 month (Trinidad *et al*. 1997) despite a good result can be found. There are numerous studies regarding CA storage for several mango varieties, yet there are no complete recommendations for 'Palmer' mangoes. Teixeira and Durigan (2011) reported a delay in the ripening process and better fruit quality when 'Palmer' mangoes were stored in CA containing 1–10 kPa O2 at 12.8 °C for up to twenty-eight days, however there are not any studies regarding the consequences of CO_2.

2.5. Effects of Storage Temperature and Relative Humidity

Keeping intact and fresh-cut fruits within their optimum ranges of temperature and relative humidity is the most important factor in maintaining their quality and minimizing postharvest losses. Above the minimum safe temperature for mango as a chilling-sensitive commodity, every 10 °C increase in temperature accelerates

deterioration and the rate of loss in nutritional quality by 2 to 3 fold. Quantitative losses (due to water loss and decay) and Qualitative losses (losses in flavor and nutritional quality) might be due to delays between harvesting and cooling or processing. The extent of those losses depends upon the commodity's condition at harvest and its temperature, which may be several degrees higher that ambient temperatures, especially when exposed to the hot water treatment.

Chantanawaran (2000) found that the CO_2 production rate of mango cubes stored at 5 ºC was higher than those of mango cubes stored at 2 ºC and 0 ºC, respectively. However, the C_2H_4 production of mango cubes stored at 0 ºC was about 2.5 times above those stores at 5 ºC and 2 ºC. Normally, supported temperature effects, produce kept at lower temperature should have lower CO_2 and C_2H_4 production. However, increased respiration and ethylene production rates showed at chilling temperatures as result of many chilling sensitive fruits and vegetables. Therefore, the higher Temperature management is the most critical factor in the management of ripening in mature-green mangoes. Paull and Chen (2004) [15] indicate that holding the fruit within the temperature range of 20 to 23 °C (68.0 to 73.4 °F) provides the simplest appearance, palatability and decay control when ripening mangoes. According to, Paull and Chen (2004) [15] reports mature green mangoes can be detained at 10 to 13 °C (50 to 55°F) for 14 to 28 days. Ripe mangoes can be detained at 10 to 13 °C (50 to 55°F) for up to one week. Kader and Mitcham (2008) [10] show that holding the fruit between 15.5 to 18 °C (60 to 65°F) during ripening offers the most attractive skin color, however the flavor remains sour unless the fruit are detained an additional 2-3 days at 21-24 °C (70-75°F). The skin of the fruit becomes mottled and therefore the fruit acquire a robust flavor if mangoes are detained at 27-30 °C (80-86°F) during ripening. If mangoes are held above 30 °C (86°F), ripening is retarded.

Kader and Mitcham (2008) [10] indicate if detained below 13 °C (55°F) for mature green mangoes, and below 10 °C (50 °F) for partially ripe mangoes, being a tropical fruit, mangoes are subject to chilling injury. Ripe mangoes are often held in air storage at 10 °C (50 °F) for a couple of days without chilling injury. Kader and Mitcham (2008) [10] note that, so as to avoid the danger of chilling injury to the fruit, it might be preferable to carry mature-green mangoes or mangoes at the breaker stage during a controlled atmosphere chamber with 4% oxygen (with the balance of the atmosphere being nitrogen) and a temperature of 15 °C (59°F) than during a normal air environment at 10 °C (50 °F) when attempting to delay ripening. The ripening or storage facility should be within the 90 to 95% range of humidity of the air to avoid fruit dehydration (shrivel).

Simulations have shown that temperature influences processes involved in fruit growth at the sink level, i.e. fruit demand and rate of growth . The contribution of temperature to fruit demand are often related to the variation in degree-days wont to compute fruit demand within the model of mango growth in dry mass (Léchaudel *et al*., 2005a). during this study, the model predicted the observed response of fruit growth to changes in temperature between seasons among controlling conditions of carbon and water supplies. Leaf nitrogen on a neighborhood basis, and Na (calculated because the Nm-to-Ma ratio) on mango which reflects photosynthetic capacity, was linearly associated with the fraction of intercepted light in reality.

However, this effect was significantly smaller than another source-sink factor, the initial fruit dry mass representing fruit size after cellular division. This factor, which reflects the entire number of cells in fruit flesh, are often influenced by temperature as well. It has been suggested in other species, including Satsuma mandarin. (Marsh *et al*., 1999) and apples (Austin *et al*., 1999), that temperature may affect the speed of cellular division. Other preharvest factors like resource limitation during cellular division due, for instance, to carbon competition, are often a source of variation of the initial fruit dry mass.

2.6. Control of Temperature and Relative Humidity

Temperature and immersion time play a serious role in determining mango fruit quality after treatment and through storage. Improper HWT in terms of unfavorable higher temperature or increasing dipping times may result in skin scalding, lenticels spotting and retention of unripe starchy areas in mango flesh (stem end cavity). (Paull & Arnstrong, 1994) [14]. The degree of injury caused by HWT varies in cultivar. Since mango is rich in nutritional compounds with health promoting properties, especially for his or her antioxidant properties, from consumer's point of view it's essential to understand whether HWT affects the antioxidant and nutritional property of the fruit after harvest. According to Kim *et al*. (2009) [11], HWT at 46.1 °C reduced the entire soluble phenolics and antioxidant capacity 4 days after storage regardless of the treatment duration.

The findings of Kim *et al*. (2009) [11] enable to conclude that fruit subjected to HWT has the likelihood of losing some nutritional benefits thanks to heat triggering oxidation processes during prolonged storage and transport, especially when arriving by sea shipment. During ripening, starch is converted to sugar thanks to the hydrolysis of starch granules within the chloroplast (Selvaraj and Kumar, 1989). Sugar production from starch was reduced by HWT (45 °C for 75 min or 48 °C for 60 min). Increase in dipping temperature during HWT directly affected the event of carotenoid content within the flesh. On the other hand, HWT at higher temperatures like 52 °C for 20 min was observed to reinforce complexion development during ripening (Jacobi & Wong, 1991) [8]. Sensory properties with reference to texture were suffering from HWT temperature and dipping time. Mature-green mango are commonly ripened at destination. During ripening temperature management is a crucial factor. Mature-green mangoes ripened at 20–23 °C showed good appearance and eating quality (Paull & Chen, 2004) [15].

According to Kader and Mitcham (2008) [10], complexion improved when fruit were held at 15.5 to 18 °C, but the flavour remained tart. Paull and Chen (2004) [15] showed that holding the fruit within the temperature range of 20 to 23 °C (68.0 to 73.4 °F) offers the simplest appearance, palatability and decay control when ripening mangoes. Kader and Mitcham (2008) [10] indicate that holding the fruit between 15.5 to 18 °C (60 to 65°F) during ripening provides the foremost attractive complexion, however the flavour remains tart unless the fruit are held a further 2-3 days at 21-24 °C (70-75°F). The skin of the fruit becomes mottled, if mangoes are held at 27-30 °C (80-86°F) during ripening, and therefore the fruit obtain a robust flavor. When mangoes are held above 30 °C (86°F), ripening is retarded. Mature-green mangoes are often held at 10 to 13 °C (50 to 55°F) for 14 to twenty-eight days (Paull and Chen, 2004). Ripe mangoes are often held at 10 to 13 °C (50 to 55°F) for up to at least one week.

3. Summary and Conclusion

Temperature management is the greatest critical factor affecting the post-harvest shelf life of mango. If mangoes ripening in the temperature range of 20 to 23 °C (68.0 to 73.4 °F) will end in fruit of the simplest appearance, palatability, and decay control. Mangoes are often held at 10 to 13 °C (50 to 55°F) to increase their time period. Holding mangoes outside these temperature ranges will end in fruit with but optimal quality, and may injure the fruit. The ripening rate are often accelerated by the treatment of mature-green mangoes with 100-ppm ethylene for twenty-four hours. Relative humidity of 90 to 95% should be maintained during all post-harvest handling steps to attenuate water loss and shriveling of mango.

Fruit quality plays a serious role in determining consumer acceptance of the fruit at the international markets. Therefore, mango exporting countries must enforce adequate quality assurance systems and post-harvest management practices to maintain fruit quality during the export chain. Temperature management during storage and shipping may be a critical factor that affects fruit quality at destinations, and mangoes should be stored and shipped at 8–13 °C (depending on cultivar and duration) and at 85–90% RH. After arrival, proper temperature management has to be practiced at storage or at the retailers' shelf (8–14 °C). Decay and quality deterioration are the major post-harvest problems of mango fruit during the export chain.

4. Recommendation

According to the review of this paper, It will suggest researchers to focus and done further research on the cause of temperature and relative humidity on shelf life of mango fruit with respective to quality.

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