**Chapter I**

*Introduction*

Watermelon (*Citrullus lanatus* Thunb) is a wonderful fruit with high glycemic index (Foster-Powell et al., 2002), enormous antioxidant potential and low calorific value. It accounted for 5.3% of the global cultivated area under fruit production in 2012 (FAO, 2016). Watermelon is grown in hot and dry climate with mean temperature of 22-30°C and low rainfall. The shape of fruit varies from globular to oblong. The fruit is consumed in hot and dry season on account of its cool, refreshing, delicate flavour and attractive color (Tressler & Josslyn, 1971). The surplus produce can be utilized to obtain bio-pigment, oil, protein and pectin etc. It will help in reducing the environmental pollution as well as economic loss to farmers.

Watermelon is a non-climacteric fruit and its maturity is judged by dull sound when the fruit is thumped, withering of tendril at the fruit axil, ground spot turning yellow, flesh color turning red and rind starts yielding to pressure. Environmental conditions during production such as light intensity, temperature and irrigation can alter lycopene content by 10-20% (Perkins-Veazie et al., 2001; Leskovar et al., 2004). Several biochemical, physiological and structural modifications take place during ripening (Dragovic-Uzelac et al., 2007) resulting in change of color, texture, flavour and aroma (Chisari et al., 2010). Soluble solids show an increasing trend whereas total acidity, protein, total polyphenolic contents show a decreasing trend. Synthesis of carotenoids within the chromoplasts in watermelon fruit results in characteristic red coloration (Perkins-Veazie et al., 2006; Grassi et al., 2013). Fruit becomes soft due to progressive degradation of cell walls and delicious due to changes in aromatic compounds, organic acids and soluble sugars (Barcelo et al., 1992; Seymour et al., 1993).

The post harvest storage study of watermelon is important in relation to nutritional quality and processing characteristics. During post harvest storage, various changes occur in fresh watermelon such as the loss of moisture occur due to transpiration and respiration, decrease in total soluble solids (Yau et al., 2010), loss of sweetness due to enzymatic activity, change in flesh firmness (Radulovic et al., 2007) and synthesis of carotenoids increases in lycopene content (Perkins-Veazie & Collins, 2006). The usual postharvest life of watermelon is 14-21 days at 13°C (Rushing et al., 2001).
Lycopene accounts for 84-97% of total carotenoids (Perkins-Veazie & Collins, 2006; Kang et al., 2010). It is a bio-color, anticancer drug, free radical scavenger and oxygen quencher. The singlet oxygen quenching activity of lycopene \((17 \times 10^9 \text{ M}^{-1}\text{s}^{-1})\) is more than \(\beta\)-carotene \((13 \times 10^9 \text{ M}^{-1}\text{s}^{-1})\) (Di-Mascio et al., 1989; Conn et al., 1991). Lycopene protects DNA against oxidative damage resulting in prevention of chronic cancers such as colon, lung, stomach, oral cavity, cervix, prostate, pancreas, rectum, oesophagus and breast (Giovannucci, 1999; Bramley, 2000; Weisburger, 2002; Omoni & Aluko, 2005), atherogenesis, and cell proliferation (Agarwal & Rao, 2000; Arab et al., 2002; Weisburger, 2002). Lycopene is dominant pigment in red fleshed, \(\beta\)-carotene in orange fleshed whereas \(\beta\)-carotene and xanthophylls in yellow fleshed watermelons (Watanabe et al., 1987). Red fleshed watermelons contain lycopene content of 3.79-7.12 mg/100g on fresh weight basis (Perkins-Veazie et al., 2001), 3.38-8.23 mg/100g fresh weight basis (Perkins-Veazie et al., 2006) and 6.22-11.34 mg/100g fresh weight basis (Soteriou et al., 2014). Pharmaceuticals, food and cosmetic industries have high demand for lycopene (Borguini & Torres, 2009).

Watermelon juice is utilized for the production of mixed juices, nectars, fruit cocktails, concentrates and powder. Processing of watermelon juice is a good strategy to handle surplus produce in peak season. The juice is vulnerable to microbial and enzymatic deterioration due to high water activity. The removal of moisture causes the reduction in enzymatic and microbial activity (Karim & Hawlader, 2005; Kaya et al., 2007). Watermelon juice concentration is a heat and mass transfer process that increases the soluble solids content and viscosity whereas exposure to heat degrades heat sensitive constituents like lycopene (Sogi, 2003). Dehydration of fruit juices can be carried out by spray drying (Bhandari et al., 1993; Quek et al., 2007; Gomes et al., 2014) and freeze drying (Arya et al., 1985) techniques. The sugars such as fructose, glucose, sucrose and organic acids such as citric, malic and tartaric acid present in fruit juices are responsible for stickiness of dried juice powder (Dolinsky et al., 2000; Adhikari et al., 2004). Maltodextrin, consisting of \(\beta\)-D-glucose units can be added to fruit juices to obtain free flowing powder with high product stability (Reineccius, 1991; Bhandari et al., 1993, Silva et al., 2006).

Watermelon processing produces huge quantities of solid waste. The previous studies on watermelon have reported 41.5-60% juice, 8.9-23.59% pomace and 31-49.55% rind (Shin et al., 1978; Crandall & Kesterson, 1981; Uddin & Nanjundaswamy, 2006; Kang et al., 2010). It is a bio-color, anticancer drug, free radical scavenger and oxygen quencher. The singlet oxygen quenching activity of lycopene \((17 \times 10^9 \text{ M}^{-1}\text{s}^{-1})\) is more than \(\beta\)-carotene \((13 \times 10^9 \text{ M}^{-1}\text{s}^{-1})\) (Di-Mascio et al., 1989; Conn et al., 1991). Lycopene protects DNA against oxidative damage resulting in prevention of chronic cancers such as colon, lung, stomach, oral cavity, cervix, prostate, pancreas, rectum, oesophagus and breast (Giovannucci, 1999; Bramley, 2000; Weisburger, 2002; Omoni & Aluko, 2005), atherogenesis, and cell proliferation (Agarwal & Rao, 2000; Arab et al., 2002; Weisburger, 2002). Lycopene is dominant pigment in red fleshed, \(\beta\)-carotene in orange fleshed whereas \(\beta\)-carotene and xanthophylls in yellow fleshed watermelons (Watanabe et al., 1987). Red fleshed watermelons contain lycopene content of 3.79-7.12 mg/100g on fresh weight basis (Perkins-Veazie et al., 2001), 3.38-8.23 mg/100g fresh weight basis (Perkins-Veazie et al., 2006) and 6.22-11.34 mg/100g fresh weight basis (Soteriou et al., 2014). Pharmaceuticals, food and cosmetic industries have high demand for lycopene (Borguini & Torres, 2009).

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Watermelon pomace, containing more lycopene (20mg/100g) than juice (Perkins-Veazie et al., 2006) has potential application in food products to increase their neutraceutical value. The pomace can be utilized as animal feed like poultry, cattle, swine, aquaculture etc. or as a fuel in boilers or extraction of pectin and fibers. Utilization of watermelon waste for pigment can reduce the problem of disposal and increase value addition. However, high moisture content (>92%) of pomace makes it susceptible to microbial spoilage leading to environmental problems (Kerje & Grum, 2003). Drying of solid waste can overcome this problem and open various avenues of its utilization for the extraction of bioactive compounds. Sorption behaviour of dried product affects the physico-chemical properties and storage life (Rizvi, 1995). Sorption data is required for designing dryers, storage structures and packaging material.

Lycopene can be extracted from watermelon pulp using conventional food grade organic solvents. Stability of lycopene extracts obtained with these solvents is higher than chloroform, methanol, dichloromethane (Taungbodhitham et al., 1998). Extraction efficiency of solvents is impaired due to poor penetration of solvent into the compact tissues of the fruit and incomplete solubilization of pigment. The extraction efficiency can be improved by optimizing the process parameters. High temperature helps to increase the extraction rate of lycopene by destroying structures of cells (Chang et al., 2006) and decrease the interaction between lycopene and its tissue matrix. Response surface methodology (RSM) is used to design experiments that yield the relevant information in shortest time with least cost.

Coloring isolated from watermelon is a semi solid mixture of pigments, fats, fatty acid and sterols obtained by the solvent extraction (Moyler, 1999). It can be used in preparations of beverages, curry powders, soup powders, confectioneries, noodles, sauces, canned meat. Lycopene is an unstable pigment and can be degraded with effect of light, oxygen and heat through the reaction of oxidation and isomerization (Schierle et al., 1997; Nguyen & Schwartz, 1999, Shi & Le Maguer, 2000). The degradation of lycopene has direct impact on the sensory quality, natural appearance and health benefits of finished products (Shi et al., 2002). Consumer demand for health promoting products provides an opportunity to develop lycopene rich functional foods and nutraceutical products. Utilization of lycopene as a food color depends on formulation, method of preparation and manufacturing techniques. Lycopene is authorized as a food color in European Commission (EC) and listed as E 160d in Directive 95/45/EC.
Effectiveness of lycopene depends on its bioavailability and ability to maintain its antioxidant properties in vivo. The survival rate of X-radiated mice can be increased with curative effects of lycopene (Forssberg et al., 1959). In vivo studies have shown a tumor-suppressive activity of lycopene (Stahl & Sies, 1996). The cholesterol levels in the blood can reduce with intake of lycopene (Rao & Agarwal, 1999). Lycopene was superior to α- and β-carotene in inhibiting cell proliferation in various human epithelial cell lines (Levy et al., 1995). The process of carotenoids absorption involves the release of carotenoids from the food matrix, improved by mechanical and enzymatic disruption, incorporation into lipid droplets, dissolution into mixed micelles, intestinal uptake, incorporation into chylomicrons, distribution to the tissues, uptake by the liver, re secretion into very low-density lipoproteins and then progressively transformed into low-density lipoproteins (Richelle et al., 2002). The cis-lycopene isomers have higher bioavailability compared to all trans-lycopene (Boileau et al., 2002). Significant reduction in oxidation of serum lipid, protein and DNA can be achieved with intake of 25-30mg lycopene daily (Rao & Agarwal, 1999).

The study has been designed to utilize the watermelon fruit with following objectives:

- Physico-chemical changes during development and storage of fresh watermelon.
- Changes in lycopene content during processing of watermelon juice into concentrate and powder.
- Study of drying characteristics and moisture sorption isotherms of watermelon pomace.
- Extraction optimization of lycopene from watermelon pulp and preparation of coloring.
- Antioxidant properties and stability of coloring under different storage conditions.
- In vivo bioavailability of lycopene.
- Utilization of pigment in food products.