Research Article

The Present Review Focus on Preparation of Dehydrated Tomato Powder by Different Drying Condition with Pre-Treatments

Vishal Kumar*, Sweta Singh and B. R. Singh

Department of Agricultural Engineering and Food Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110 (U.P.)

Abstract

The study of this research, dehydrated tomato powder was prepared by different drying conditions with pre-treatments. Drying is the moisture removing process from the products. Drying reduces the bacterial growth in the products. Tomatoes are commonly consumed fresh; over 80% of the tomato consumption comes from processed products such as tomato juice, ketchup and sauce. Recent studies have indicated the potential health benefits of a diet that is rich in tomatoes. It will be helpful for preserving the products for long time. Dehydration process was carried out using a cabinet tray dryer, solar dryer, freeze drying methods with different thickness of tomato slices at same temperature of cabinet tray dryer, freeze dryer and solar dryer according on atmosphere temperature conditions. The effect of three pre-drying treatments on quality of cabinet dried tomato powder was analyzed by determining moisture content, rehydration ratio, dehydration ratio, overall drying rate, total sugar, acidity, optical density, pH, vitamin-C and sensory analysis.

Keywords: Drying methods, dried tomato, drying rate, lycopene

***Correspondence**
Author: Vishal Kumar
Email: vishalkumarsingh129@gmail.com

Introduction

Worldwide, tomato is considered an important agricultural crop and an integral part of the human diet. Although these are commonly consumed fresh, more than over 80% of the tomato consumption comes from processed products such as tomato juice, ketchup and sauce. Recent studies have indicated the potential health benefits of a diet that is rich in tomatoes. Lycopene, a mayor carotenoid without pro-vitamin an activity, present in red tomatoes, is considered responsible for their beneficial effects [1, 2]. At present the demand for the tomatoes is increasing steadily with an increase in population. India is the 4th major tomato producing country in the world next to China. Also the major exporter of tomatoes to Pakistan, Bangladesh, U.A.E, Nepal, Maldives and Oman [3].

When tomatoes are processed into products, 10 to 30% of their weight becomes waste or “pomace” [4]. It is also fiber rich feed resource and thought to act as a cholesterol reducing feedstuff in poultry products [5]. Tomatoes are climacteric in nature [6]. Climacteric fruits submitted to gamma irradiation exhibit a delay of ripening [7-9]. In the specific case of tomatoes, irradiation generally delays ripening when the treatment is applied at the pre-climacteric stage [10, 11].

Methods for Drying

Drying is one of the oldest methods of food preservation technique and it represents a very important aspect of food processing. Drying is a process of removing excess water content from an agricultural or industrial product. It is the oldest method of food preservation. Most of the agricultural product contain the higher moisture of 25–80% but generally for agricultural products. It is around 70%. This value of moisture content is very much higher than the required for long preservation. Due to the bacterial and fungal growth is very fast in the crops. Bacteria and enzymes may spoil the foodstuff and reduces the nutrient content in it. Moisture content of crops to a certain level slows down the bacterial, enzymes, and yeasts effect [12]

Cabinet tray dryer/Foam Mat Drying

In tray dryers, the food is spread out, generally quite thinly, on trays in which the drying takes place. Heating may be by an air current sweeping across the trays, by conduction from heated trays or heated shelves on which the trays lie, or by radiation from heated surfaces. Most tray dryers are heated by air, which also removes the moist vapours.

According to Sheshma and Raj, [13] Prepared tomato powder was prepared by drying fresh and healthy tomato. Before drying sample of tomatoes were subjected to different pre-treatments such as calcium chloride ($CaCl_2$), potassium metabisulphite (KMS), calcium chloride and potassium metabisulphite ($CaCl_2$ + KMS) and sodium chloride (NaCl). Untreated samples served as control. After Pre-treatments, tomatoes were cutting and sliced. Then, solar dryer and tray dryer were used for dehydration. Drying process was done at temperature of 37 ^{0}C and 60-70 ^{0}C. At the bone dry condition, samples were ground in a grinder and after grinding all the samples were packaged in HDPE. Quality characteristics of tomato powder viz. moisture content, titratable acidity, lycopene content, dehydration ratio, rehydration ratio and non-enzymatic browning (NEB) as affected by dehydration process were studied for a period of 2 months for tomato powder packed into HDPE packaging materials. Pre-treated samples for tray dryer in HDPE bag was selected as the best dehydration process.

In this studied during drying process, some nutrients may degrade and thus, affect general quality characteristics of the dried tomato. The effect of pre-treatment in enhancing drying and product quality of dried tomato was determined study. Slices of tomato were treated by dipping in (a) A solution containing 0.5% sodium metabisulphite for 10 min and (b) 0.1% ascorbic acid +0.1% citric acid solution for 10 min (1:1) and (c) distilled water for 10 min (control). Convection dehydration was carried out on tomato slices using as total solids, lycopene the least lycopene degradation, highest dehydration ratio (19.40±1.03) and also facilitated the drying of tomato better than the other treatments [14].

According to by Sangamithra *et. al.,* [15] Foam mat drying is an economical alternative to drum, spray and freeze-drying for the production of food powders. The liquid is whipped to form stable foam, and dehydrated by thermal means. The larger surface area of the foam accelerated the drying process for the rapid moisture removal from the high moisture feed. A high-quality food powder can be obtained by the proper selection of foaming method, foaming agents, foam stabilizers, time taken for foaming, suitable drying method and temperature. In this article, the basics of foam and its structure, methods of foaming, types of foaming method and stabilizing agents for the production of stable foam have been analyzed. The influence of foaming agents and foaming properties on the drying characteristics of fruit juices are also studied. This article reviewed the application of foam drying process for different food materials, the microstructure and the quality of powders obtained by using different foaming agents.

According to Sharada, [16] the foam mat drying is a good way of dehydrating liquids foods in short times. Due to the porous structure of the foamed materials, mass transfer is enhanced leading to shorter dehydration times. This technique can be successfully employed for drying a variety of fruit juice concentration and pulps. The dried powders have good reconstitution characteristics. These studies are particularly applicable for drying of fruit and vegetable pulps drying such as guava, bananas and tomato etc. with some of the commonly used foaming agents like egg albumin and soya protein. The drying studies are carried out in a tray drier. The drying curves are drawn with different operating parameters and foaming agents. Falling rate is observed for the foam at different timings. Drying rates are compared and the drying time is evaluated by drying the foam at 55 ^{o}C to 80 ^{o}C.

The foaming properties include the capacity of formation of an air in water dispersion, which is due to the volume expansion of the dispersion promoted by an emulsifier with incorporation of air through whipping, agitation or aeration techniques. The main advantages of foam drying are lower temperatures and shorter drying times compared to drying non-foamed materials in the same dryer type [17]. The structure, expansion and stability of the foam provide an important function in the movement of the moisture during drying and, consequently, in the food quality [18].

Green House Type Solar Dryer

Solar food drying can be used in most areas but how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. Typical drying times in solar dryers range from 1 to 3 days depending on sun, air movement, humidity and the type of food to be dried. According to Rayes *et. al.,* [19] Tomato pieces were dehydrated in a hybrid solar dryer provided with a 3 m^2 solar panel and electric resistances. At the outlet of the tray dryer 80 or 90% of the air was recycled and the air temperature was adjusted 50 or 60 ºC. At the outlet of the solar panel the air temperature raised between 5 and 18 °C above the ambient temperature.

According to Arun *et. al.,* [20] the performance of the dryer was studied (drying time and product quality) in comparison with open sun drying method. It was found that the solar tunnel greenhouse dryer took only 29 hours for reducing the moisture content of tomatoes from 90% (w.b.) to 9% (w.b.) whereas the open sun drying took 74 hours for the same. Also, the qualities of dried tomatoes produced from solar tunnel dryer are much superior compared to that of open sun drying.

Freeze Drying

Food products that are too sensitive to withstand any heat are often freeze-dried. Freeze dehydration is an operation in which water is removed from foods by transfer from the solid state (ice) to the gaseous state (water vapour). This operation (sublimation) can only be accomplished when the vapour pressure and temperature of the ice surface at which the sublimation takes place below those at the triple point. Food structure is affected differently by sublimation than by other methods of dehydration because of a liquid phase during freeze dehydration. The sublimated ice is pulled from the vacuum chamber by vacuum pumps or steam jet injectors. The heat of sublimation is supplied by conduction or radiation. It is well known that freeze-drying produces the highest-quality food product. In this studies by Ahlawat and Punia, [21] An attempt has been made in the present investigation to observe the effect of solar tunnel drying and freeze drying techniques on the organoleptic acceptability of products developed by incorporating okara which was extracted, processed (dried) and powdered from variety PS-1347. Five products namely doughnuts, macroni, cake-rusk, noodles and butter cookies were prepared by incorporating various proportions (10, 20 and 30 per cent) of processed okara. It was observed that noodles, macroni and cake rusk of freeze dried okara were most acceptable at 30% level and fell in the category between liked moderately and liked very much by having 7.9, 7.7 and 7.6 overall mean scores, respectively. Whereas, doughnuts and butter cookies prepared by substituting 20% solar tunnel dried okara were found most acceptable having 7.5 and 7.8 mean scores, respectively.

Freeze-drying is a process whereby water is removed by dehydration, through sublimation of ice in the materials. It is generally recommended for drying of materials containing heat-sensitive antioxidant components such as tocopherols, ascorbic acid, carotenoids and plant phenolics. Freeze-drying is known to extend the shelf-life of foods by preventing the microbial growth and retarding lipid oxidation [22]. It is also applied for long-term storage of foods for the purposes of preserving on industrial scale [23]. Moreover, during freeze-drying treatment, there may be a chance of decline in the content of antioxidants due to degradation of certain compounds. Besides, the freeze-drying operational cost is also high [24]. In some previous studies, losses of food vitamins and nutritional value due to freeze-drying have been reported [25, 26].

Physico-Chemical Changes during Dehydration

According to Hasanuzzaman *et. al.,* [27] the research was to develop a self-stable dehydrated tomato product using different sugar solutions and to study the effects of the sugar solution on the characteristic of tomato candy. Tomato was immersed into the sugar solution with the concentrations of 40%, 50% and 60% for 24 hours. Moisture, ash, protein, fat, vitamin C, acidity, total sugar, crude fiber, total SO_2 and salt content and organoleptic quality and microbiological status of the prepared candy were analyzed. There was a tendency of decreasing moisture, ash, protein, fat, vitamin C, acidity, crude fiber and increasing total sugar content with increased concentration of sugar solution used.

In this study by sittu *et al.,* [28] processed fruit and vegetables such as sun dried tomatoes can be categorized as ambient temperature shelf life stable products. The present study through systematic theoretical assertions temperature of 10, 30 and 45 ^{0}C. results showed that in this temperature range, upper limit moisture content varied between 6%-7.5% and 6.5%-8.3% d.b. for absorption, respectively. The corresponding lower limit moisture content varied between 4.29%-5.52% and 5.15% and 6.29% d.b. In order to minimize moisture migration into or out dried slice during storage, the study revealed that the product should be stored within 29%-62% relative humidity.

According to Joaquina *et. al.,* [29] in this study, the storage at all temperature had significant impact on the quality parameters analysed. Significant alterations in tomato green colour, firmness and weight loss were observed. The result also revealed a slight increase in the total phenolic content, and that refrigeration storage at 2 and 5 ^{0}C induced chilling injuries. In this studies by Misha *et. al.,* [30] Application of tray dryer is widely used in agricultural drying because of its simple design and capability to dry products at high volume. However, the greatest drawback of the tray dryer is uneven drying because of poor airflow distribution in the drying chamber. Implementing the proper design of a tray dryer system may eliminate or reduce non-uniformity of drying and increase dryer efficiency. This paper discussed several design of tray dryer system for drying agricultural products and its performance. Most of the dryer system have been developed are using solar energy because the system run at low operating chamber configuration by predicting the airflow distribution and the temperature profile throughout the drying chamber.

Figure 1 Drying tomato slices

Figure 2 Tomato Powder

Storage and Quality

During the drying process and storage periods conditions, oxidative damage takes place in tomato [31-34]. In this study by [35], they indicated that the main causes of lycopene degradationduring processing and storage are isomerisation and oxidation.

According to this studied [36, 37] Browning index, which is an indicator of the extent of browning, was higher in solar dried samples than tray dried. Direct exposure of thin slices of tomato for longer time of dehydration may be considered as reason of these changes. Lycopene is also a potent neuroprotective [38], antiproliferative, anticancer [39], antiflammatory, cogntion enhancer [40] and hypocholesterolemic agent [41]. Lycopene also modulates cyclo-oxygenase synthesis pathway [42]. Lycopene has been under considerable investigation for its antioxidant benefits in treating various chronic human diseases like cancer, cardiovascular diseases, osteoporosis and diabetes [43]. A diet rich in tomatoes and tomato products might also prevent cancer and cardiovascular disease. Lycopene, the natural antioxidant that gives ripe tomato fruits and tomato products their characteristic deep red colour is considered to be behind these beneficial health effects [44-47]. Several studies have indicated that lycopene levels remain relatively stable during thermal processing [46, 48, 49, 61]. Studies concerning the effects of drying on tomato antioxidant components has demonstrated that the lycopene in tomatoes is substantially stable during industrial drying [31, 46, 49, 50].

Colour Quality Effect on Drying Process

Therefore, understanding those factors affecting TSS and TA contents is important for quality evaluation. Previous studies have investigated the non-thermal factors that affect TA and TSS contents of fresh tomato [51-53] and the effect of processing temperatures on TSS and TA of tomato paste [54-56]**.** No literature was found on the effect of hot-air drying on TSS content of tomato slices. Recently, [57] reported that drying of tomato slices caused an increase in soluble solids and acidity, while pH and AA decreased. Processing conditions such as high temperature, long duration of exposure and the presence of oxygen shown to contribute to increased degradation of lycopene [58].

Browning Reactions

Browning reactions decrease nutritional value and solubility, create off-flavours, and induce textural alterations in the food. Such reactions are classified into enzymatic and non-enzymatic reactions. The former are enzyme-mediated reactions while examples of the latter include sugar caramelization, sugar-amine reactions (Maillard reactions) and ascorbic acid oxidation [59-61]**.**

Enzymatic Browning

Enzymatic browning occurs in fruits and vegetables such as bananas, pears, mushrooms and potatoes, often upon bruising during handling or when sliced under the presence of air, as well as during the drying process. Protective measures against discoloration by enzymatic browning reactions include the inactivation of enzymes by blanching or heat treatments at temperatures of around 70 to 75 ^{o}C, the use of reductive agents such as sulphur dioxide or ascorbic acid, and the removal of available oxygen [62].

Non-Enzymatic Browning Reactions

The most common types of non-enzymatic browning during drying are Maillard reactions in which carbonyl groups of reducing sugars, aldehydes and ketones interact with amino compounds such as amino acids, peptides and proteins. These reactions result in brown pigments, known as melanoidins, causing the main discoloration problem in dried products such as white dried soups, tomato soup and other dried fruit and vegetables [63].

Rehydration Ability

Rehydration may be described as a process in which dried material is submerged in a fluid (most commonly water) for moistening purposes. However in general, the water that is removed during drying cannot be replaced in exactly the same manner to yield a product identical to the original material. This phenomenon is due to irreversible cellular and structural damage that occurs in plant tissue during drying. Such damage includes loss of turgor pressure in the cell, loss of differential permeability in the protoplasmic membrane, crystallization of polysaccharide gels in the cell wall and coagulation of protoplasmic proteins.

Sensory Evaluation

After the preparation of tomato powder, 4 samples were selected for organoleptic evaluation according to the method as described by [64]. The Organoleptic evaluations of tomato powder were carried out by 10 judges. All the judges formed the panel were conversant with the factor governing the quality of the sample. Tomato powder was evaluated organoleptically for color, flavor, texture and overall acceptability.

These findings are also in consistent with findings of [65] who found out that vitamin C and honey treated samples scored higher in texture than control and further stated that the pre-treatments affects the rate of moisture loss during drying which conserves the tenderness of the outer surface unlike untreated samples when moisture diffusion is very fast hence roughness of the surface of dried pineapples. For the flavour, the results are similar to those outlined by [16]**,** who reported that pineapples contain sucrose, fructose and glucose in concentrations which gives it a good taste, which in combination with some acids and other compounds determine the typical flavour of pineapple fruit The colour and taste of the dried samples were significantly affected by the pre-treatments.

The lower scores for colour in control samples could also be explained by the findings as reported by [30] who stated that colour changes of materials during dehydration is not only due to evaporation of the surface water but also due to certain reactions such as enzymatic browning and Caramelizations and it is assumed that the pre-treatments might have played a part in reducing these reactions resulting in better colour than in control samples.

References

[1] Rao, A.V., Zeeshaw, W. and Agarwal, S. (1998). Lycopene content of tomatoes and tomato products and their contribution to dietary Lycopene, Food Research International, v.31, n.10, pp. 737-741.

[2] Shi, J.; Marc, Le M; Kakuda Y; Liptay A. and Niekamp, F. (1997). Lycopene degradation and isomerisation in tomato dehydration. Journal of Food Engineering, Vol.34: pp.429-440, Great Britain.

[3] Anonymous (2001). The Eighth Growth plan of Turkey. DPT 2636 OİK 644. Ankara- Turkey pp 1-83.

[4] King, A.J. and Zeidler G. (2004).Tomato Pomace May be a Good Source of Vitamin E in Broiler Diets. California Agriculture, Vol.58(1).

[5] Al-Betawi, N.A., (2005). Preliminary Study on Tomato Pomace as Unusual Feedstuff in Broiler Diets. Pak. J. Nutr., Vol 4: pp 57-63.

[6] Saltveit, M.E., 2005. Fruit Ripening Fruit Quality. In: Heuvelink, E. (Ed.), Tomatoes. CAB International, Wallingford, UK, pp: 145-170.

[7] Akamine, E.K. and Moy, J.H. (1983). Delay in Post Harvest Ripening and Senescence of Fruits. In: Josphson, E.S. and M.S. Peterson (Eds.), Preservation of Food by Ionizing Radiation. CRC Press, Boca Raton, Fl., 111: pp 129-158.

[8] Thomas, P., (1988). Radiation preservation of food of plants origin. Part VI. Mushrooms, tomatoes, minor fruits and vegetables, dried fruits and nuts. CRC Crit. Rev. Food Sci. Nutr., Vol.24: pp 313-358.

[9] Urbain, W.M., (1986). Food Irradiation. Academic Press, Orlando, FL: New York.

[10] Abdel-Kader, A.S.; Morris, L.L. and Maxie, E.C. (1968). Physiological studies of gamma irradiation of tomato fruits. I. Effect on respiratory rate, ethylene production and ripening. Proc. Amer. Hort. Sci., Vol.92: pp 553-567.

[11] Lee, T.H.; W.H. Mc, Glasson and R.A. Edwards (1968). Effects of gamma irradiation on tomato fruit picked at four stages of development. Radiat. Bot., Vol.8: pp 259-267.

[12] Belessiotis, V. and Delyannis, E. (2011). Solar drying. Solar Energy, Vol.85: pp1665- 1691.

[13] Sheshma, Jyoti and Raj, John, D. (2014). Effect of pre-drying treatments on quality characteristics of dehydrated tomato powder. International Journal of Research in Engineering & Advanced Technology. Vol.2(3): pp 1-7.

[14] Owureku-Asare, Mavis; Joyce, Agyei-Amponsah; Firibu, Saalia; Luis, Alfaro; Luis A. Espinoza-Rodezno and Subramaniam, Sathivel (2014). Effect of pretreatment on physicochemical quality characteristics of a dried tomato (Lycopersicon esculentum). African Journal of Food Science. Vol. 8(5): pp- 253-259.

[15] Sangamithra, A.; Sivakumar, Venkatachalam; Swamy, Gabriela, John and Kannan, Kuppuswamy (2014). Foam mat drying of food materials: A review Journal of Food Processing and Preservation. Vol.10.1111:12421.

[16] Sharda, S. (2013). Studies on effect of various operating parameters & foaming agents- drying of fruit and vegetables. International Journal of Modern Engineering Research. Vol.3(3):pp 1512-1519.

[17] Thuwapanichayanan, R.; Prachayawarakorn, S. and Soponronnarit, S. (2012). Effects of foaming agents and foam density on drying characteristics and textural property of banana foams. LWT - Food Science and Technology, Zürich, v. 47, p. 348-357.

[18] Bag, S. K. and Srivastav, P. P. (2011). Optimization of process parameters for foaming of bael (Aegle marmelos L.) fruit pulp. Food and Bioprocess Technology, Vol. 4(8), pp. 1450-1458.

[19] Rayes, A.; Mahn, A.; Huenulaf, P. and Gonzalez, T. (2014). Tomato dehydration in a hybrid-solar dryer. Chemical Engineering & Process Technology. Vol.5(4): pp 1-08.

[20] Arun, S.; Ayyappan, S. and Sreenarayanan, V.V. (2014). Experimental studies on drying characteristics of tomato in a solar tunnel greenhouse dryer. International Journal of Recent Technology and Engineering. Vol.03(04):pp 32-37.

[21] Ahlawat, Deepika and Punia, Darshan (2014). Effect of solar tunnel and freeze drying techniques on the organoleptic acceptability of products prepared incorporating okara (soy by-product). International Journal of Food and Nutritional Sciences.Vol.03(03), pp 10-13.

[22] Marques, L.G.; Prado, M.M. and Freire, J.T. (2009). Rehydration characteristics of freeze- dried tropical fruits. J. Food Sci. Technol. Vol.42: pp 1232–1237.

[23] Pérez-Gregorio, M.R.; Garcia-Falcon, M.S. and Simal-Gandara, J. (2011). Flavonoids changes in fresh-cut onions during storage in different packaging systems. Food Chem. Vol.124: pp 652–658.

[24] Marques, L.G.; Silveira, A.M. and Freire, J.T. (2006). Freeze-drying characteristics of tropical fruits. Drying Technol., Vol.24: pp 457–463.

[25] Chang, C.; Lin, H.; Chang, C. and Liu, Y. (2006) Comparisons on the Antioxidant Properties of Fresh, Freeze-Dried and Hot-Air-Dried Tomatoes. Journal of Food Engineering Vol.77(3): pp 478-485.

[26] Murcia, M.A.; Lopez-Ayerra, B.; Martinez-Tome, M.; Vera, A.M. and Garcia- Carmon, F. 2000. Evolution of ascorbic acid and the peroxidise during industrial processing of broccoli. J. Sci. Food Agric., Vol.80: pp 1882–1886.

[27] Hasanuzzaman, Md.; Kamruzzaman, M.; Mominul, Md.; Islam; Sultana, Anjuman, Ara, Khanom; Md. Mashiar Rahman; Laisa Ahmed Lisa and Dipak, Kumar Paul (2014). A study on tomato prepared by dehydration technique using different sugar solutions. Food and Nutrition Sciences, Vol.5; pp 1261-1271.

[28] Sittu, S. K. and Isiaka, M. (2013). Storage stability of dried tomato slice. International Journal Agric. & Biol. Engg. Vol.06 (04): pp 104-110.

[29] Joaquina, Pinheiro; Carla, Alegria; Marta, Abreu; Elsa, M. Goncalves and Cristina, L. M. Silva. (2013). Kinetics of changes in the physical quality parameters of fresh tomato fruits (Solanum lycopersicum, cv. ‘Zinac’) during storage.Journal of Food Engineering. Vol.114; pp 338- 345.

[30] Misha, S.; Mat, S.; Ruslam, M.H.; Sopian, K. and Salleh, E. (2013). Review on the application of a tray dryer system for agricultural products. World Applied Sciences Journal. Vol.22(03). pp: 424-433.

[31] Zanoni, B.; Peri, C.; Nani, R. and Lavelli, V. (1999): Oxidative Heat Damage of Tomato Halves as Affected by Drying. Food Research International, Vol.31(5): pp 395-401.

[32] Toor, R.K. and Savage, G.P. (2006). Effect of semi-drying on the antioxidant components of tomatoes. Food Chem. Vol.94: pp 90-97.

[33] Sharma, S.K. and Le, Maguer, M. (1996). Kinetics of lycopene degradation in tomato pulp solids under different processing conditions. Food Res. Int. 29: 309-315.

[34] Zanoni, B.; Pagliarini, E. and Foschino, R. (2000). Study of the stability of dried tomato halves during shelf-life to minimize oxidation damage. J. Sci. Food Agric. Vol.80: pp 22030-2208.

[35] Shi, J. and Le Maguer, M. (2000). Lycopene in Tomatoes: Chemical and Physical Properties Affected by Food Processing. Critical Reviews in Food Science and Nutrition 40 (1): pp1-42.

[36] Baloch, W.A.; Khan, S. and Baloch, A.K. (1997). Stability of tomato powder at intermediate moisture levels. Journal of Food Science and Technology (Mysore).

[37] Simon, M.; Wagner, J. R.; Silveira, V. G. and Hendel, C. E. (1995). "Calcium chloride as Non-Enzymatic Browning Retardant for Dehydrated White potatoes," Food Tech., vol. 12: pp. 271-275.

[38] Hisao, G.; Fong, T.H.; Tzu, N.H.; Lin, K.H.; Chou, D.S. and Sheu, J.R. (2004). A potent antioxidant, lycopene, affords neuroprotection against microglia activation and focal cerebral ischemia in rats. In Vivo; Vol.18: pp 351- 356.

[39] Gunasekera, R.S.; Sewgobind, K.; Desai, S.; Dunn, L.; Black, H.S. and McKeehan, W.L. (2007). Lycopene and lutein inhibit proliferation in rat prostate carcinoma cells. Nutr. Cancer. Vol.58: pp171-177.

[40] Akboraly, N.T.; Faure, H.; Gourlet, V.; Favier, A. and Berr, C. (2007). Plasma carotenoid levels and cognitive performance in an elderly population: results of the EVA Study. J. Gerontol. A Biol. Sci. Med. Sci. Vol.62: pp 308- 316.

[41] Riso P, Visioli F, Grande S, Guarnieri S, Gardana C, Simonetti P (2006). Effect of a tomato-based drink on markers of inflammation, immunomodulation and oxidative stress. J. Agric. Food Chem. Vol.54: pp 2563-2566.

[42] Sengupta, A.; Ghosh, S.; Das, R.K.; Bhattacharjee, S. and Bhattacharya, S. (2006). Chemopreventive potential of diallylsulfide, lycopene and theaflavin during chemically induced colon carcinogenesis in rat colon through modulation of cyclooxygenase-2 and inducible nitric oxide synthase pathways. Eur. J. Cancer Prev. Vol.15: pp 301-305.

[43] Rao, A.V. and Rao, L.G. (2007). Carotenoids and human health. Pharmacol Res. Vol.55: pp 207-216.
[44] Clinton, S.K. (1998). Lycopene: Chemistry, biology and implications for human health and disease. Nutr. Rev. Vol.56: pp 35-51.
[45] Giovannucci, E. (1999). Tomatoes, Tomato-Based Products, Lycopene, and Cancer: Review of the Epidemiologic Literature. Journal of National Cancer Institute, Vol.91(4): pp 317-331.
[46] Kaur, C.; Binoy, G.; Deepa, N.; Singh, B. and Kapoor, H. C. (2004) Antioxidant Status of Fresh and Processed Tomato- A Review. Journal of Food Science and Technology Vol.41 (5): pp 479-486.
[47] Porrini, M.; Riso, P. and Testolin, G. (1998). Absorption of Lycopene from Single or Daily Portions of Raw and Processed Tomato. British Journal of Nutrition Vol.80: pp 353-361.
[48] Abushita, A. A.; Daood, H. G. and Biacs, P. A. (2000). Change in Carotenoids and Antioxidant Vitamins in Tomato as a Function of Varietal and Technological Factors. Journal of Agricultural Food Chemistry. Vol. 48: pp 2075-2081.
[49] Giovanelli, G.; Paradiso, A. (2002). Stability of Dried and Intermediate Moisture Tomato Pulp during Storage. Journal of Agricultural Food and Chemistry Vol.50: pp 7277- 7281.
[50] Takeoka, G. R.; Dao, l.; Flessa, S.; Gillespie, D. M.; Jewell, W. T.; Huebner, B.; Bertow, D. and Ebeler, E. S. 2001: processing effects on lycopene content and antioxidant activity of tomatoes. Journal of agricultural food chemistry Vol.49: pp 3713-3717.
[51] Lavelli, V.; Hippeli, S.; Peri, C. and Elstner, E. F. (1999) Evaluation of Radical Scavenging Activity of Fresh and Air Dried Tomatoes by Three Model Reactions. Journal of Agricultural and Food Chemistry Vol.47: pp 3826-3831.
[52] Anza, M.; Riga, P. and Garbisu, C. (2006). Effects of variety and growth season onthe organoleptic and nutritional quality of hydroponically grown tomato. J Food Qual. Vol. 29: pp16_37.
[53] Polenta, G.; Lucangeli, C.; Budde, C.; Gonzalez, C.B. and Murray, R. (2006). Heat and anaerobic treatments affected physiological and biochemical parameters in tomato fruits. LWT Food Sci Technol Vol.39: pp 27-34.
[54] Thybo, K.; Edelenbos, M.; Christensen, L.; Sørensen, J. and Thorup-Kristensen, K. (2006). Effect of organic growing systems on sensory quality and chemical composition of tomatoes. LWT Food Sci Technol 39:835_843.
[55] Sherkatl F, Luh B. 1976. Quality factors of tomato pastes made at several break temperatures. J Agric Food Chem.Vol. 24: pp 1155-1158.
[56] Anese, M.; Calligaris, S.; Cristina, Nicoli, M. and Massini, R. (2003). Influence of total solids concentration and temperature on the changes in redox potential of tomato pastes. Int J Food Sci Technol Vol.38: pp 55-61.
[57] Khazaei, J.; Chegini, G. and Bakhshiani, M. (2008) A novel alternative method for modelling the effect of air dry temperature and slice thickness on qualityand drying kinetics of tomato slices: Superposition technique. Drying Technol. Vol.26: pp759- 775.
[58] Preedy, V. R. (2012). Vitamin A and carotenoids: Chemistry, analysis, function and effects. United Kingdom: Royal society of chemistry. 583 p. ISBN 978-1-849-73368- 7.
[59] Krokida, M. and Maroulis, Z. (2000) Quality Changes during Drying of Food Materials. In: Mujumdar, S. A. (Edt): Drying Technology in Agriculture and Food Sciences. Enfield: Science Publishers, Inc: pp 61-106.
[60] Okos, R. M.; Narsimhan, G.; Singh, R. K. and Weitnauer, A. C. (1992): Food Dehydration. In: Heldman, D.R.; Lund, D. B. (Edt): Handbook of Food Engineering. New York: Marcel Dekker, Inc. pp-437-562.
[61] Rahman, S. M. and Perera, O. C. (1999). Drying and Food Preservation. In: Rahman, S. M. (Edt): Handbook of Food Preservation. New York: Marcel Dekker, Inc: pp173- 216.
[62] Hutchings, J. B. (1999). Food Colour and Appearance.Gaithersburg: Aspen Publishers, Inc.
[63] Jayaraman, K. S.; Gupta, Das and D. K. (1995) Drying of Fruits and Vegetables. In: Mujumdar, S. A. (Edt): Handbook of Industrial Drying, Vol. 1, New York: Marcel Dekker, Inc: pp 643-690.
[64] Stone, C.V. (1985). Sensory Evaluation Prattices. Florida: Academic Press. pp 311.
[65] Panagiotou, N.M.; Karathanos, V.T.; Maroulis, Z.B. (1998). Mass transfer modeling of the osmotic dehydration of some fruits. International J. Food Sci. Technol. Vol.33(3): pp 267-284.

Publication History

Received	11th Jan 2017
Revised	10th Feb 2017
Accepted	11th Feb 2017
Online	28th Feb 2017