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DIFFERENT QUALITY CHARACTERISTICS OF TOMATO (*SOLANUM LYCOPERSICUM*) AS A FORTIFYING INGREDIENT IN FOOD PRODUCTS: A REVIEW

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A b s t r a c t

Tomato (*Solanum lycopersicum*) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. The objective of this paper is to review nutritional benefits of tomato, its different bioactive components and their application in food products. Tomato and tomato products are very beneficial to our health as they decrease the risk of many diseases, such as cancer, asthma, heart disease etc. The whole fruit of tomato i.e pomace, seed and tomato solids have many nutraceutical benefits and is extensively used in food processing industry either as raw or in powder form. Many bioactive components are present in tomato, such as lycopene, oleoresin, carotenoids etc. Tomato is very popular for high content of antioxidant compounds and antioxidant activity. It is preserved mainly by drying (tray drying, freeze drying) and encapsulation process. We have tried to focus on to get the answer, which one is better in food application, lycopene supplementation or direct tomato powder fortification in food products.

Introduction

Tomatoes *(Solanum lycopersicum)* are one of the most widely used and versatile vegetable crops. They are consumed fresh and are also used to manufacture a wide range of processed products (MADHAVI and SALUNKHE

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1998). Tomatoes and tomato products are rich in health-related food components. United States, Turkey, Italy, and Spain are the leading tomato growing countries (JUMAH et al. 2004). The advantages of using tomato by-products as food ingredients are noticeable both to reduce environmental pollution and to provide an extra-income for producers (LAVELLI and SCARAFONI 2012). Tomato can be consumed as raw or as an ingredient in many dishes, sauces, salads, and drinks. Factors influencing the considerable increase in tomato consumption include consumer awareness of benefits such as preventing cancer and chronic diseases (LANA and TIJSKENS 2006). This beneficial effect is due to the action of antioxidant compounds, which reduce oxidative damage in the body (BEECHER 1998). Tomatoes are rich in lycopene (87%) and other carotenoids such as carotene, phytoene, phytofluene, lutein and L-ascorbic acid (SOMA 2013). Lycopene is a carotenoid that can be incorporated into foods with the purposes of conferring both color and functional characteristics (NUNES and MERCADANTE 2007). Lycopene has attracted attention due to its biological and physicochemical properties, especially related to its effects as a natural antioxidant. Lycopene does exhibit a physical quenching rate constant with singlet oxygen almost twice as high as that of beta-carotene (SHI and LE MAGUER 2000). Several food technology studies have been carried out to optimize the processing and storage of the tomato products by preventing the heat and oxidative damage on the antioxidants (SHI et al. 1999). Tomatoes are not as sweet due to its lower sugar content then other edible fruits. Tomatoes are low in calories and a good source of vitamins A and C, the flavor, texture, and cooking characteristics of tomatoes depend on the variety, growing method, local environment, and handling techniques used during and after harvest (PARNELL et al. 2004). Most of the tomatoes are processed for its juice, ketchup, sauce, paste, puree and powder. Flavor characteristics of tomatoes are an important purchasing criterion (KRUMBEIN et al. 2004). Researchers have reported that lack of flavor of tomato is associated with various storage treatments, e.g., modified atmosphere (HO 1996, HOBSON 1988, MAUL et al. 2000). Dried tomato products (i.e., tomato halves, slices and powders) are in high consumption as compared to other tomato products due to their excellent properties (ARSLAN and OZCAN 2011). Tomato solids in powder form have many advantages, including ease of packing, transportation and mixing, and no drum-clinging loss (GIOVANELLI et al. 2000).

Nutritional benefits of tomato derivatives

Skin

The by-products of tomato processing (skin) contain a very high amount of lycopene. In particular, tomato skin has 2.5 times higher lycopene level than the pulp (SHI et al. 1999). Tomato skin contains more than 20 ppm lycopene, protected within the chromoplasts in the cells. Besides serving as a micronutrient with important health benefits, lycopene is an excellent natural food colorant (LAVELLI and TORRESANI 2011). Tomato skin contains more than 70% (w/w, db) of dietary fibre. Tomato skin fibre is mainly insoluble (ZEINAB et al. 2010). The use of dried tomato skin in powder form are proposed as an addition to refined oils for carotenoid solubilization in view of upgrading low quality oils, in the formulation of ketchup, in dry fermented sausages, and in beef hamburgers (BENAKMOUM et al. 2008, CALVO et al. 2008, FARAHNAKY et al. 2008, GARCÍA et al. 2009). The skin powder also provides proteins, cellulose and pectins, thus representing a good candidate to be used to modulate water sorption and rheological properties of food. Indeed the use of skin powders in the formulation of ketchup, improves its textural properties (FARAHNAKY et al. 2008). Approximately one-third of the total weight of tomatoes in the form of skin and seeds is discarded during processing of tomatoes into paste (TOOR and SAVAGE 2005).

Seed

Seeds are the major part of the pomace, and they are, 34% protein and 30% lipid (weight basis). Seed proteins have been extracted to produce protein concentrate (SAVADKOOHI and FARAHNAKY 2012). Studies on nutritive value of tomato seed proteins *in vivo* could not be found, however, reports involving the use of microorganism and enzymes are available. CANELLA and CASTRIOTTA (1980) reported that the tomato-seed protein is a mixture of globulin, albumin, prolamine and glutelin components. Tomato-seed protein components are adsorbed at oil-water (o/w) interfaces and reduce the interfacial tension considerably. Furthermore, compared to isolated soy protein, tomato proteins produce emulsions with greater globule size (SAVADKOOHI and FARAHNAKY 2012). Tomato seed protein is rich in lysine (approximately 13% more lysine than soya protein) and can supplement feed that is deficient in lysine (LAVELLI and TORRESANI 2011). Tomato seed was dried and fortified in bread and has significant effect on antioxidant activity, nutritional and sensory profile analysis (RANAWANA et al. 2016). Tomato seed was used to replace corn and soyabean meal and it is healthy diet (based on protein efficiency ratio, amino acid content and digestibility) for chick (PERSIA et al. 2003).

Pomace

Tomato pomace is an inexpensive by-product of tomato manufacturing, contains almost 75% water and the cost of shipping tends to be very high (due to its weight). The conventional procedure for tomato processing generates heat-treated tomato pomace (skins and seeds); in contrast, a new plant operates the pulping/finishing steps on raw fruits at room temperature, thus producing an unheated pomace (SAVADKOOHI and FARAHNAKY 2012). Dehydrated tomato pomace as a by-product of tomato production lines can be used for animal feed or human food. Tomato pomace contains high levels of polysaccharides, such as fiber and pectin (YUANGLANG et al. 2010). It increasingly has been used as valuable feed stuff in ruminants and poultry nutrition in developing countries. Tomato pomace is the mixture of tomato peels, crushed seeds and small amounts of pulp that remains after the processing of tomato for juice, paste and ketchup (AGHAJANZADEH et al. 2010, VENTURA et al. 2009, KING and ZEIDLER 2004). It contains 5.1% moisture, 11.9% fat, 26.8% protein and 26.3% crude fiber (YITBAREK 2013) Moreover, it contains 13% more lysine than soybean protein, a good source of vitamin B, fair source of vitamin A and 2130 kcal/kg metabolizable energy (AL-BETAWI 2005). Tomatoes contain a solanine-like alkaloid (saponin) called tomatine which have medicinal properties such as antibiotic, anticancer, anti cholesterol, anti inflammatory and anti pyretic affects (CALVO et al. 2008).

Tomato solids

Tomato powder is much in demand by dehydrated soup manufacturers, and it also can be used as an ingredient in many food products, mainly soups, sauces and ketchup. The skin powder also provides proteins, cellulose and pectins, thus representing good characteristics to be used to modulate water sorption and rheological properties of food (PAPADAKIS et al. 1998). The solubility of the powder is associated with the moisture content and operational conditions of the dryer, increasing with decrease in the moisture content (GOULA and ADAMOPOULOS 2005, PAIVA and RUSSELL 1999).

Bioactive components of tomato

The main bioactive compound of tomato which lycopene is discussed below and the other bioactive components oleoresin, phenol and flavonoid, carotenoid and ascorbic acid are discussed in table 2.

Lycopene

Lycopene, a member of carotenoid family; is a lipid soluble antioxidant synthesized by many plants and microorganisms but not by animals and humans. It serves as an accessory light-gathering pigment and protects the plant against the toxic effects of oxygen and light. Tomato (lycopene, 8.8–42 μg/g W/W) and its derivative mainly represent main dietary sources of lycopene, but also watermelon, papaya, guava and pink grapes are rich sources. It is the naturally occurring compound that gives the characteristic red color to the tomato, watermelon, pink grapefruit, orange, and apricot (RAO and AGARWAL 2000). Lycopene has polynutrient, in many fruits and vegetables it consist of the potent antioxidant. Tomatoes and processed tomato products constitute the major source of dietary lycopene accounting for up to 85% of the daily intake (CHAUHAN et al. 2011).

Lycopene content of various fruits and vegetables were represented in Table 1 (NGUYEN and SCHWARTZ 1998).

Table 1

Lycopene content of various fruits and vegetables

Foods	Lycopene content (mg/100 g)
Tomato foods	
Tomatoes, raw	0.9–4.2
Tomatoes, cooked	3.7–4.4
Tomato sauce	7.3–18.0
Tomato paste	5.4–55.5
Tomato soup (condensed)	8.0–10.9
Tomato juice	5.0–11.6
Ketchup	9.9–13.4
Other fruits and vegetables	
Apricots, fresh	0.005
Watermelon, fresh	2.3–7.2
Papaya, fresh	2.0–5.3
Grapefruit, pink/red	0.2–3.4
Guava, raw	5.3–5.5
Vegetable juice	7.3-9.7

Source: NGUYEN and SCHWARTZ (1998)

The lycopene levels are lower for peeled tomatoes as the removed peel is known to have higher content. It was reported that the concentration of lycopene is two folds higher in pericarp than in locular cavity and β-carotene is four folds higher in locular cavity (CHAUHAN et al. 2011). Lycopene

Table 2

Some other bioactive components in tomato apart from lycopene

Name of the bioactive component	Oleoresin	Carotenoid	Phenol and flavonoid	Ascorbic acid
Composition	Tomato oleoresin is a semisolid mixture of a resin and essential oil (RIZK et al. 2014).	Tomato carotenoids include compounds called carotenes and xanthophylls (BRAMLEY 2002).	Phenolics include flavonoids, phenolic acids. Phenol such as- hydroxybenzoic and hydroxycinnamic acids, and tannins. And flavonoid such as quercetin and kaempferol, flavanols catechins, Naringerin, anthocyanidins (MARTIN and APPEL 2010).	L-ascorbic acid and dehydroascorbic acid are the main dietary forms of vitamin C, a labile molecule with reducing property. It is a water-soluble compound easily absorbed but it is not stored in the body (PADAYATTY et al. 2003).
Application and use	Oleoresins have medicinal properties, used mainly as a flavoring agent in the food processing industry such as dairy products, non alcoholic flavored drinks, cereal and cereal products, bread and baked goods because it is more economical to use and it gives a consistent quality to the food products (LUCERA et al. 2012).	The carotenoids in tomatoes are yellow, orange and red pigment that act as antioxidants to help protect cells and is a natural cancer fighting agent (BRAMLEY 2002).	Maintain of heart health neutralizes free radicals; associated with therapeutic tools in inflammatory diseases incuding obesity, neurodegenerative disease, diabetes, cancer and aging (RAHMAN 2007).	Vitamin C in tomato is highly bioavailable, so a regular intake of small amounts of tomato products can increase cell protection from DNA damage induced by oxidant species (PADAYATTY et al. 2003).

is a highly unsaturated straight chain hydrocarbon with a total of 13 double bonds, 11 of which are conjugated. *In vitro* studies have shown lycopene to be twice as potent as β-carotene and ten times that of α-tocopherol in terms of its singlet oxygen quenching ability (ALI et al. 2010). Lycopene in raw tomatoes is generally present as the all-*trans* geometric isomer, the most thermodynamically stable form. Lycopene, either as a pure agent or as part of tomato components, can be incorporated into semi-purified diets for studies of carcinogenesis or tumorigenesis (NGUYEN and SCHWARTZ 1998). Moreover, several studies suggested that lycopene is a more potent scavenger of oxygen radicals than other major dietary carotenoids (GAJIC et al. 2006). Lycopene in tomatoes are found in association with protein complex or membrane structure, which prevent lycopene digestion and absorption. Harsh treatments during food processing, such as mechanical texture disruption and steam, may denature the lycopene-protein complex and release lycopene from the cellular matrix (SHI et al. 2004).

Lycopene metabolism

The enzymatic metabolism of lycopene and other carotenoids is only beginning to be understood. Lycopene, like β-carotene, when metabolized by carotenoid monooxygenase 2 will generate apo lycopenals (KHACHIK et al. 1995). The major metabolite of lycopene identified in human plasma is 5,6-dihydroxy-5,6-dihydrolycopene, probably due to the oxidation of lycopene via conversion from intermediate lycopene epoxides (ERDMAN et al. 1993).

Relationship between bioavailability and bioaccessibility with lycopene

Accessibility of lycopene is mainly influenced by crystalline formation called bioavailability. The bioavailability of /cis/-isomers in food is higher than that of all /trans/-isomers. Lycopene bioavailability in processed tomato products is higher than in unprocessed fresh tomatoes (SHI et al. 2000). Lycopene absorption was found to be apparently more efficient at low dosages than at higher dosages, possibly due to the low potential to form crystals at low dosages (STAHL and SIES 1992). Ultrasound processing can cause decrease in lycopene bioaccessibility, due to lycopene entrapment in the stronger network of pectin, making it less accessible for digestion. The effects of lipids on lycopene bioaccessibilty are the use of lycopene as food supplement dissolved in a lipophilic carrier, which can improve the lycopene bioavailability (BEEBY and POTTER 1992).

Preservation methods for tomato

Drying

Drying is a complex process of removal of moisture from wet material by means of thermal energy where both heat and mass transfer take place. Many physical, chemical, and nutritional changes occur in foods during the dehydration process (ROBERTS et al. 2008). Though food drying indicates the loss of volatiles and flavors, changes in color and texture, and minimally decrease in nutritional value, drying is the useful means to increase the shelf life of perishable food for further use (MARS and SCHER 1990). During processing and storage a number of changes occur in dried tomato products. It is reported that the moisture content, bulk density and solubility of tomato powder, three most commonly quoted specifications of a powder product, were all dependent on the spray drying conditions, i.e. air inlet temperature, drying air flow rate, and compressed air flow rate (CHAUHAN et al. 2011). Sousa et al observed spray drying operational condition on tomato and analysed moisture content, solubility, consistency, wettability and color index (SOUSA et al. 2008). Freeze drying was done on tomato peel and tomato peel powder effect was analyzed on physicochemical properties after incorporation of extruded snack (ZEINAB et al. 2010). Tomato was dried by solar drying and color retention and rehydration ratio was analyzed (RAJKUMAR et al. 2007). Drying kinetics and quality attributes of oven dried tomato powder were analyzed (ABANO et al. 2011). Antioxidant content, color and rehydration ratio were studied on tray dried tomato powder (SANCHEZ et al. 2012). To investigate the effect of temperature and osmotic dehydration on air drying kinetics, quality and moisture removal tomato pomace was dried by cabinet air oven (AL MUHTASEB et al. 2010). Different drying methods used for preparing various tomato products are given in Table 3.

Encapsulation

Microencapsulation is a technique by which solid, liquid or gaseous active ingredients are packaged within a second material from the surrounding environment for the purpose of shielding the active ingredient (DUBEY et al. 2009). Microencapsulation allows the creation of a physical barrier between the core and the wall materials (FAVARO-TRINDADE et al. 2008). A convenient and simple procedure for the formation of microcapsules is the method known as complex coacervation (GOUIN 2004, GÜLAY and SEDA 2014). Encapsulated natural colors such as carotenoids, anthocyanins, and chlorophylls are easier to handle and offer improved stability to oxidation and solubility

Table 3

Different drying methods of tomato

Tomato drying process	Observation	References
Tray drying	To incorporate tomato powder in place of artificial coloring and flavoring agent in the fudge and to evaluate its sensory and microbial parameters and antioxidant activity.	SOMA 2013
	Antioxidant content, color and rehydration ratio were analysed.	SANCHEZ et al. 2012
Spray drying	The effects of the spray dryer operational conditions on the moisture content, solubility, consistency, wettability and color index were analyzed.	SOUSA et al. 2008
Freeze drying	Physico chemical property of extruded snack with tomato peel powder was analysed.	ZEINAB et al. 2010
	Lycopene content, product density, hardness, percentage of moisture loss and color parameters of the snacks evaluated.	
Solar drying	Color retention and rehydration ratio were analyzed.	RAJKUMAR et al. 2007
Laboratory solar drying	Effect of different drying thickness and drying kinetics of tomato slices.	BAGHERI et al. 2013
Cabinet air oven drying	To investigate the effect of temperature and osmotic dehydration on air drying kinetics and quality of tomato pomace and to asses moisture removal.	AL MUHTASEB et al. 2010
Hot air oven drying	To study drying kinetics and quality attributes of tomato slices.	ABANO et al. 2011

(DUBEY et al. 2009). Lycopene was encapsulated in powder form by spray drying and inclusion freeze drying process (NUNES and MERCADANTE 2007). Carotenoid rich extract was obtained from tomato paste and it was encapsulated by inulin in a prebiotics matrix system. Encapsulated carotenoid was used for formulation of functional foods (CLARA et al. 2011).

Application

Tomato, either as a whole or as powder form has several uses in different food industries to prepare cookies, snacks, jelly, sauce, ketch up etc.

Tomato powder vs lycopene supplement

Many researchers have suggested that tomato can be used in powder form as well as as lycopene supplement. The points below are discussion on the

application of both the tomato powder and lycopene supplement in food industry.

Tomato powder

Tomato powder has good potential as substitute of tomato paste and other tomato products; the final quality of dehydrated products is affected by the drying conditions. Among several processing methods spray drying is the efficient mode of preservation of tomato powder. The temperatures and drying conditions experienced by a droplet during the drying have an important influence on the powder properties (BENAKMOUM et al. 2008). Tomato powder is readily marketable due to ease in packaging, transportation and utilization in different ready to eat food preparations with extended storage life. The quality of dehydrated tomato depends on many parameters such as tomato variety, total soluble solid content (^{o}Brix) of the fresh product, the air humidity, the size of the tomato segments, the air temperature and velocity and the efficiency of the drying system. The dehydrated powder was packed in polythene bags and kept in glass bottles at room temperature; here the peroxide value increases with storage period, indicating deterioration (REIHANEH and MEHDI 2010).

Uses

– The tomato powder used in soups, instant sauce premixes, ketchups, sambar and rasam mix, puddings, bakery products, health foods, sweets, biscuits, baby foods, confectioneries, snacks etc.

– They are also used in the preparation of recipes viz., tomato dosa, soup, rice and burfi and compared with fresh tomato recipes. As the powder is in the concentrated form, it gave attractive appearance, color and taste to the recipes.

– Tomato skin powder was incorporated into refined oils for carotenoid solubilisation in view of upgrading low quality oils.

The use of skin powders in the formulation of ketchup, improves its textural properties (SHU et al. 2006).

Lycopene supplement

Researchers observed that the stability of microencapsulated lycopene was significantly higher when compared to the free material such as lycopene obtained by spray drying using gelatin, sucrose and modified starch. Human

populations consume lycopene from both food and supplements (ROCHA et al. 2012). Lycopene is an important issue in nutrition due to the bioavailability of a bioactive substance. The lycopene taken as a supplement is easy to the body as a food substitute. Recent studies have suggested a protective role for lycopene, an antioxidant carotenoid, in the prevention of oxidative stress (GAJIC et al. 2006).

Uses

– Lycopene was used for preventing heart disease, (atherosclerosis) and cancer of the prostate, breast, lung, bladder, ovaries, colon, and pancreas.

– Lycopene is also used for treating human papilloma virus (HPV) infection, which is a major cause of uterine cancer.

– Some people also use lycopene for cataracts and asthma.

The application of tomato in food products is represented in Table 4.

Table 4

Application of tomato in food products

Tomato by products	Use in type of food	Observation	References
Tomato powder	Cookies	Physico chemical, color, texture and sensory parameters.	CHUNG 2007
Tomato peels	Ice cream	Carotenoid content, antioxidant content and sensory parameter analysed.	RIZK et al. 2014
Tomato seed meal	Bread	Physico chemical property analysed	SOGI et al. 2005
Tomato peel, tomato powder and lycopene	Beef patties, sausages, minced meat and frankfruters	The presence of lycopene from different tomato matrices leads to a better colour in the meat products, improved nutritional quality, reduced lipid oxidation and increased stability during the shelf life period and retaining overall acceptability.	CANDOGAN 2002, CALVO et al. 2008, ØSTERLIE and LERFALL 2005, DEDA et al. 2007
Tomato skin powder	Refined oil	For carotenoid solubilisation in view of upgrading lowo quality oils	BENAKMOUM et al. 2008

Conclusion

Tomatoes are the most valuable and are the most commonly used crops in many food dishes. They are very much beneficial to our health due to their antioxidant properties. Tomato contains high concentration of lycopene, L-ascorbic acid, oleoresin, phenol, flavonoids and carotenoid. Dietary intake of tomatoes and tomato products decreases chronic diseases, cardiovascular diseases and also reduces certain risk of cancer. Various tomato products are made from tomato skin, seed, pomace and are very much useful in our diet. Now -a-days tomato in powder form are mainly used due to their excellent nutrient properties in the formulations of ketchup, soups, sauces and they can also act as a natural colorant. Tomato powder can easily be handled, preserved and stored, have low transportation cost. The shelf life of tomato powder is much more than raw tomatoes. Hence, tomato is very useful for our body due to its great antioxidant properties, health effects, and in enzymatic metabolism. It is always better to use tomato powder than only lycopene for the purpose of food fortification.

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