

# The Role of Parry Tomato Lycopene Complex in Human Health

July 2011



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**Key words:** *Parry Tomato Lycopene Complex, Lycopene, Tomato, Parry, Carotenoid, Phyto-nutrient, Prostate Health, Bone Health*



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## Introduction

Lycopene is a red plant pigment found in tomatoes, apricots, guavas, watermelons, papayas, pink grapefruits and rosehips, with tomatoes being the largest contributor to the dietary intake of humans (Chalabi et al., 2004). Chemically it is a 40-carbon acyclic carotenoid which contains 11 conjugated double bonds and belongs to a sub-group of carotenes consisting only of hydrogen and carbon atoms (Stahl and Sies, 1996). These eleven conjugated double bonds give it a deep red color and are responsible for its antioxidant activity. Lycopene exhibits higher singlet oxygen (O<sub>2</sub>) quenching ability. Due to its strong color and non-toxicity, lycopene is a useful food coloring (registered as E160d).

Lycopene is not an essential nutrient for humans, but is commonly found in the diet, mainly from dishes prepared with tomato sauce. When absorbed from the stomach, lycopene is transported in the blood by various lipoproteins and accumulates in the liver, adrenal glands, and testes.

## Dietary Sources

Lycopene is present in variety of colored fruit and vegetable. At least 85% of our dietary lycopene comes from tomato fruit and tomato-based products, the remainder being obtained from watermelon, pink grapefruit, guava and papaya (Table 1). Of the tomato products: juice, ketchup, soup and pizza and spaghetti sauces are the major contributors in the diet (Table 1). The range of values is related to varietals differences and the effects of growth conditions on carotenoid synthesis. The configuration of lycopene in these crops is predominantly all-trans, though processed tomato products contain between 1.7% and 10.1% cis isomers. Processing also affects the matrix of the tomato product (Shi and Le Mageur, 2000).

**Table 1: Lycopene Content of Fruit and Tomato Products**

Fruit/Tomato Product	Lycopene Content (ug/g wet weight)
Fresh tomato	8.8±42.0
Watermelon	23.0±72.0
Pink guava	54.0
Pink grapefruit	33.6
Papaya	20.0±53.0
Tomato sauce	62.0
Tomato paste	54.0±1500.0
Tomato juice	50.0±116.0
Tomato ketchup	99.0±134.4
Pizza sauce	127.1

*Data taken from: Scott and Hart (1995), Tonucci et al. (1995) and Rao and Agarwal (1999).*

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## Role in Human Disease

Oxidative stress, induced by reactive oxygen species (ROS), is associated with the incidence of chronic diseases such as cancer, coronary heart disease (CHD) and osteoporosis (Rao and Agarwal, 1999). ROS are highly reactive oxidant molecules that are generated endogenously through normal metabolic processes, life style activity and the diet. Antioxidants provide an effective means to combat the deleterious effects of ROS and are increasingly being considered as strategic chemo preventive agents in the management of human diseases. Lycopene a carotenoid phyto-nutrient is the most potent antioxidant naturally present in many fruits and vegetables. Lycopene in the presence of vitamin C, can repair both itself and other antioxidants to restore their antioxidant qualities. However, tomatoes and processed tomato products constitute the major source of dietary lycopene accounting for up to 85% of the daily intake (Rao and Agarwal 2000).

## Lycopene & Prostate Cancer

Lycopene has emerged from the scientific literature over the past few years to bear significant potential for consideration in both the treatment and prevention of prostate cancer.

Several epidemiology studies strongly suggest the hypothesis that the consumption of foods containing high concentrations of lycopene reduces the risk for certain types of cancer (Gann et al., 1999; Giovannucci et al., 2002; Jian et al., 2005). This hypothesis has not been upheld by many researchers who suggest that, lycopene alone may not be the compound that reduces cancer rates, but rather the group of carotenoids and nutrients as a whole may be responsible for the lower cancer rates seen in groups with higher dietary intake of tomatoes and tomato-based products (Bosetti et al., 2004).

Numerous epidemiological studies and reviews have been carried out describing the role of lycopene in association with the prevention of prostate cancer (Rao and Agarwal). One of the earliest epidemiological studies showing an inverse relationship between the consumption of tomatoes and tomato products and the risk of prostate cancer was published in 1995 (Giovannucci et al 2002). In this study, the beneficial properties of tomato products were attributed to lycopene. Since then, several other epidemiological, experimental and tissue culture studies have been reported providing further evidence for the role of lycopene in prostate cancer. One case control study in particular, conducted in 1982, examined the relationship between serum lycopene and other antioxidant levels on prostate cancer risk as well as aggressive prostate cancer incidence (Parker 1997). Odds ratios were calculated for prostate cancer incidence using logistic regression models after a thirteen-year follow-up. Lycopene was the only antioxidant for which plasma lycopene was very strongly related to lower prostate cancer risk (upper quintile odds ratio = 0.40; P, trend = 0.006 for aggressive cancer). In tissue distribution studies carried out in rats, lycopene was found in liver, testes, stomach, intestine and prostates of rats fed a tomato oleoresin. In another experiment Rao et al (1999) to know the status of oxidative stress and antioxidant in prostate cancer patient it was found that there was difference in levels of serum carotenoids and biomarker of oxidation and prostate specific levels in these subjects. Although there were no difference in the level of beta carotene, lutein, cryptoxanthin, vitamin E and vitamin A between cancer patient and

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their control, level of lycopene were significantly lower in cancer patients. As expected the PSA levels were significantly elevated in the cancer patients who also had higher levels of lipid and protein oxidation indicating higher level of oxidative stress in cancer patients. In the same study, serum PSA levels were shown to be inversely related to the serum lycopene (Rao et al 1999).

However, this area of research and the relationship with prostate cancer have been deemed insufficient of evidence for health claim approval by the US Food and Drug Administration (under Antioxidant properties and potential health benefits).

Over all, epidemiological studies, in vitro tissue culture studies, animal studies and few human intervention studies show that increase in intake of lycopene will result in increased circulatory and tissue levels of lycopene. In vivo lycopene can act as a potent antioxidant and protect cells against oxidative damage and thereby prevent or reduce the risk of several cancers. Further studies are needed to get deeper proof and to gain better understanding of the mechanisms involved.

## **Lycopene & Coronary Heart Disease (CHD)**

In vitro studies have shown that lycopene can protect native LDL from oxidation and also inhibit cholesterol synthesis (Dugas et al., 1999; Fuhrmann & Aviram 1997). Animal intervention studies have also shown lycopene to increase the resistance of the extracted LDL in vitro to oxidation. However, epidemiological studies provide the main evidence in support of the role of lycopene in the prevention of CHD (Rao 2002; Rao and Balachandran 2003; Rao and Heber 2001). In a cross sectional study (Kritenson, 1997) Lithuanian population, who are at a high risk of mortality from CHD was compared to a lower risk Swedish population and were shown to have lower blood lycopene levels. These observations suggested low blood lycopene levels to be associated with increased risk and mortality from CHD. In another case, control population study (Iribarren C, 1997), cases that exceeded 90th percentile of intima-media thickness for all arterial segments, had lower levels of lycopene.

Similarly, Rissanen et al (2000) using a randomized, double blind, placebo-controlled population study showed a direct association between low plasma lycopene concentrations and the onset of early arteriosclerosis, manifested as increased intima-media thickness of the common carotid artery, in middle-aged men living in Eastern Finland. The same authors, in a follow-up study, showed low level of serum lycopene to be associated with an increased risk of arteriosclerosis vascular events in middle-aged men who were previously free of CHD and stroke (Rao and Heber, 2001). Based on the observed inverse relationship between plasma lycopene and intima-media thickness, Gianetti et al., suggested a protective role for lycopene against arteriosclerosis (Gianetti et al., 2002). The EUEAMIC study (Kohlmeier et al., 1997) which is a multicenter case-control study evaluating the relationship between adipose tissue antioxidant status and acute myocardial infarction is perhaps the strongest population based evidence in support of the role of lycopene in the prevention of CHD. In this study, subjects recruited from 10 different European countries with acute myocardial infarctions were compared with controls. Adipose tissue samples were taken by needle aspiration biopsy procedures shortly after the infarction and used to measure  $\alpha$  and  $\beta$ -carotenes, lycopene, and alpha -tocopherol levels.

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Only lycopene, and not the other antioxidants, was found to have a significant inverse relationship with the risk of myocardial infarction (Kohlmeier et al 1999, Gomez-Aracena J et al 1997). In addition to the epidemiological studies, a few dietary intervention studies have also been reported in the literature.

In one study, upon consuming a lycopene-free diet by healthy human subjects for a period of two weeks, serum lycopene levels were reduced by 50% (Rao and Agarwal, 1998). An increase of 25% in serum lipid oxidation was also observed in this study. In another one small study, six healthy human subjects consumed 60 mg/day of lycopene for a period of 3 months. A significant 14% drop in their plasma LDL cholesterol level was observed (Fuhrmann and Elis, 1997) at the end of the treatment period suggesting a hypocholesterolemic property of lycopene. However, other studies, using different levels of lycopene intake for shorter periods of time did not report reductions in serum total or LDL cholesterol levels upon ingesting lycopene. A significant reduction in LDL oxidation was observed in another randomized, cross-over dietary intervention study (Agarwal and Rao, 1988) when 19 healthy human subjects consumed 20-150 mg lycopene daily from tomato juice, tomato sauce and a nutritional supplement for a period of one week. In summary, although there is convincing epidemiological and in vitro evidence in support of the role of lycopene in the prevention of CHD, only a few clinical trials has so far been undertaken. More dietary intervention studies are needed to fully understand the mechanisms of action of lycopene in CHD as stated diet rich in lycopene may be heart protective.

## **Lycopene & Bone Health**

Research also suggests that lycopene has lot of benefit in bone health. Oxidative stress and antioxidants may contribute to the pathogenesis of the skeletal system including osteoporosis, the most prevalent metabolic bone disease (Rao, 2006). Oxidative stress controls the functions of both osteoclasts (Silvertron and Suda et al., 1993) and osteoblasts (Liu et al., 1999). Endogenous (Key et al., 1990) and synthetic antioxidants counteract the effects of oxidative stress in these cells.

Recent studies reported that antioxidants from natural sources, such as the lycopene from tomatoes, can also counteract the damaging effects of oxidative stress. The findings that lycopene has a stimulatory effect on the cell proliferation (Kim et al., 2003) and the differentiation marker alkaline phosphatase of osteoblasts (Kim et al 2003, Park et al 1997) as well as its inhibitory effects on osteoclasts formation and resorption (Rao et al., 2003, Ishimi et al., 2003) are evidence of the involvement of lycopene in bone health and warranted further investigation in clinical studies.

Epidemiological studies have shown that oxidative stress is associated with osteoporosis and that antioxidants may counteract this effect. Certain antioxidants including vitamin C, E and beta-carotene may reduce the risk of osteoporosis [Melhus et al., 1999; Morton et al., 1999; Singh, 1992; Leveille et al., 1997] and counteract the adverse effects of oxidative stress on bone that are produced during strenuous exercise [Singh, 1992] and among smokers [Melhus, 1999]. Osteoporotic women have been shown to have reduced levels of antioxidant vitamins and enzymes indicating a decrease in their antioxidant defenses [Maggio et al., 2003].

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A recently published clinical study showed a direct correlation between serum lycopene and decrease in the risk of osteoporosis among postmenopausal women [Rao et al., 2007]. The relationship between serum lycopene, oxidative stress parameters and bone turnover markers in postmenopausal women were investigated. Study participants were asked to complete a seven-day food intake record prior to giving fasting blood samples. Oxidative stress parameters, total antioxidant capacity, serum lycopene and the bone turnover markers including bone alkaline phosphatase (bone formation) and cross-linked N-telopeptides of type I collagen (NTx) (bone resorption) were measured in the serum samples. Results showed a direct correlation between lycopene intake and serum lycopene levels. Increase in serum lycopene levels resulted in significant decreases in protein oxidation and NTx values [Rao et al., 2007]. Based on these results an important role for lycopene mediated via its antioxidant property in reducing the risk of osteoporosis is suggested. Dietary intervention studies with varying levels of lycopene are currently being conducted with the objective of demonstrating the beneficial effects of lycopene in the prevention and management of osteoporosis.

## Other Human Diseases

Hypertension is commonly referred to as the ‘silent killer’ since symptoms of this disorder is not observed until a more advanced and fatal stage of the diseases is reached. A causal relationship between oxidative stress and the incidence of hypertension is now recognized. The antioxidant property of lycopene has attracted scientific research into its protective role in hypertension.

A recent study showed lycopene supplementation at the rate of 15mg per day for 8 weeks to significantly decrease systolic blood pressures from the baseline value of 144mmHg to 134mmHg in mildly hypertensive subjects (Paran and Engelhard 2001, Paran 2006). In another study a significant reduction in plasma lycopene was observed in the hypertensive patients compared to normal subjects (Moriel et al., 2002).

When patients with liver cirrhosis, a condition closely associated with hypertension and disorders of the lymphatic circulation, were compared with matched controls, a significant reduction in serum lycopene was observed along with other carotenoid antioxidants, retinol and vitamin E in the cirrhotic group (Rao et al., 2006 , Paran and Engelhard, 2001).

Recognizing the importance of antioxidants in the management of hypertension a [‘dietary approach to control hypertension (DASH)’] diet is recommended that contains substantially higher levels of lycopene along with other carotenoids, polyphenols, flavanols, flavanones and flavan-3-ols (Most, 2004).

Male infertility, a common reproductive disorder, is now being associated with oxidative damage of the sperm leading to loss of its quality and functionality. Significant levels of ROS are detectable in the semen of up to 25% of infertile men, whereas fertile men do not produce detectable levels of ROS in their semen (Iwasaki and Gagnon 1999, Zini et al., 1993). A number of studies have reported the beneficial effects of vitamins C and E. and other antioxidants, including taurine (Alverej and Storey, 1983), l-carnitine (Monkada et al., 2002), coenzyme Q10 ( Alleva et al., 1997, Lewin and lavon, 1997), and glutathione (Lenzi et al., 1998) on sperm quality. Researchers are beginning to investigate the role of lycopene in

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protecting sperm from oxidative damage leading to infertility. Men with antibody-mediated infertility were found to have lower semen lycopene levels than fertile controls (Palan and Naz, 1996). In another study, infertile men consumed a daily dose of 8mg lycopene in capsule form. After consuming lycopene for 12 months; a significant increase in serum lycopene concentration and improvements in sperm motility, sperm motility index, sperm morphology and functional sperm concentration were observed. Lycopene treatment resulted in 36% successful pregnancies. Other studies are now in progress and their results will further advance our knowledge of the beneficial role of lycopene in male infertility. A recent review article elaborated on the possible role of lycopene in neurodegenerative diseases including Alzheimer's disease (Rao and Balachandra, 2003).

Due to high levels of oxygen uptake and utilization, high lipid content and low antioxidant capacity, human brain represents a vulnerable organ for oxidative damage. Although the role of antioxidant vitamins in neurodegenerative diseases have been reported in the literature, only a small number of studies have been reported for lycopene. Lycopene was shown to cross the blood brain barrier and be present in the central nervous system in low concentrations. Significant reduction in the levels of lycopene was reported in Parkinson's disease and vascular dementia patients (For et al., 1999). In the Austrian Stroke Prevention study, lower serum lycopene and alpha tocopherol levels were associated with increased risk of microangiopathy (Schmidt et al., 1997).

Lycopene was also suggested as providing protection against amyotrophic lateral sclerosis (ALS) disorder in humans [Longnecker et al., 2000]. When a population of elderly subjects was tested for functional capacity including the ability to perform self-care tasks, a significant positive correlation was observed between blood lycopene levels and functional capacity [Snowdon et al., 1966]. On the basis of the relationship between oxidative stress and neurodegenerative diseases and the potent antioxidant properties of lycopene, it is logical to expect further intervention studies to be carried out in the future to address this important area of human health.

Incidence of emphysema, a disorder of the lungs is reported to be high in certain countries of the world. A recent study showed protective role of lycopene in the prevention of emphysema in a mouse model. At a recent conference on the role of processed tomatoes in human health, data was provided for the protective role of lycopene in the prevention of emphysema in a Japanese population. Undoubtedly, future research will also explore the role of lycopene in other human diseases including diabetes, ocular and skin disorders, rheumatoid arthritis, periodontal diseases and inflammatory disorders [Rao et al., 2006]. The antioxidant property of lycopene is also opening up new applications in pharmaceutical, nutraceutical and cosmoceutical products [Stahl, 2006].

The scientific interest to explore innovative strategies for the prevention of human diseases underlines the common etiological and mechanistic nature of these diseases.

**Table 2: Epidemiological Studies Involving Lycopene, Lycopene-containing Foods and Chronic Diseases**

Disease	Major Conclusion	Reference
Prostate Cancer	Intake of tomato products inversely associated with prostate cancer	<i>Giovannucci et al. (1995); Clinton et al. (1996)</i>
Digestive Tract Cancer	Reduced risk with high tomato intake	<i>Franceschi et al. (1994)</i>
Bladder Cancer	Serum lycopene associated with decreased risk	<i>Helzlsour et al. (1989)</i>
Skin Cancer	Decrease in skin lycopene on exposure to light	<i>Ribago-Mercado et al. (1995)</i>
Breast Cancer	Serum lycopene associated with decreased risk	<i>Dorgan et al. (1998)</i>
Cervical Cancer	Lycopene level showed inverse risk	<i>Sengupta and Das (1999)</i>
Cardiovascular Disease	Adipose tissue lycopene associated with lower risk, low serum lycopene with increased mortality	<i>Kohlmeier et al. (1997); Kristenson et al. (1997)</i>

The hypothesis that oxidation of cellular components as an initial event eventually leading to the incidence of several diseases brings the focus to the use of antioxidants. Examples of this hypothesis include oxidation of LDL leading to increases risk of CVD; oxidation of DNA as an early step in the progression of cancers; and protein oxidation resulting in possible alterations in the activity of several metabolic enzymes and influencing many disease conditions. Lycopene by acting as an antioxidant can prevent the progression of many human diseases at an early stage and improve the quality of life.

### Daily Intake Level Estimations and Suggested Intake

It is evident that the average intake levels of lycopene are lower than required to provide its beneficial effects. In general it ranges from 3.7 to 16.2 mg. Although the beneficial effects of lycopene in the prevention of human diseases have been well documented it is not yet recognized as an essential nutrient. As a result there is no official recommended nutrient intake (RNI) level set by health professionals and government regulatory agencies. However, based on reported studies a daily intake level of 5–7 mg in normal healthy human beings may be sufficient to maintain circulating levels of lycopene at levels sufficient to combat oxidative stress and prevent chronic diseases [Rao and Shen 2002]. Under the condition of disease such as cancer and cardiovascular diseases, higher levels of lycopene ranging from 35 to 75 mg per day may be required [Heath 2006].

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Research shows that lycopene can be absorbed more efficiently by the body after it has been processed into juice, sauce, paste, or ketchup. In fresh fruit, lycopene is enclosed in the fruit tissue. Therefore, only a portion of the lycopene that is present in fresh fruit is absorbed. Processing fruit makes the lycopene more bio-available by increasing the surface area available for digestion. More significantly, the chemical form of lycopene is altered by the temperature changes involved in processing to make it more easily absorbed by the body. Also, because lycopene is fat-soluble (as are vitamins, A, D, E, and beta-carotene), absorption into tissues is improved when oil is added to the diet. Although lycopene is available in supplement form, it is likely there is a synergistic effect when it is obtained from the whole fruit instead, where other components of the fruit enhance lycopene's effectiveness.

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