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Functional Foods
REVIEW ARTICLE

Nutritional Benefits and Pharmaceutical Potentialities of Chili: A Review

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ABSTRACT

Chili (*Capsicum* spp.) is used in almost every cuisine as spices for its pungency, color and flavor. Both green and red chilies are used for preparing different palatable item such as chili chicken, chili paneer, chili sauce, chili jam etc. The plethora of nutritional and medicinal quality gives it an extra importance. Chili contains high amount of vitamin C and other vitamin such as vitamin A, vitamin B6, vitamin K and minerals like calcium, magnesium, folate, potassium, thiamin, iron, copper etc. Capsaicin is the main bioactive compound in chili which is responsible for its pungent taste and various health benefits. Capsaicin has diverse uses in pharmaceuticals that are attributed to relief of pain, anti-arthritic, anti-bacterial, anti-inflammatory, anti-rhinitis, and analgesic properties. It has also prominent role as an immunity booster for the management of cardiovascular diseases, type-2 diabetes, obesity and stops the spread of prostate cancer. The consumption of chili is reported to be related with reduced death of human being. Therefore, chili may be the beneficial component of daily diet.

INTRODUCTION

Chili (*Capsicum* spp.) is an important commercial crop that is grown all over the world. It is a dicotyledonous flowering plant and belongs to the family Solanaceae with different names such as hot pepper, chili pepper and bell pepper etc. having superfluous nutritional and medicinal value (Knapp et al. 2004; Hunziker 2001). The five domesticated species of chili peppers are *Capsicum annuum, Capsicum frutescens, Capsicum chinense, Capsicum pubescens*, and *Capsicum baccatum*. The center of diversity of chili is deemed to be in south-central South America (Gonzalez and Bosland, 1991). *Capsicum* has been known as part of the human diet as spice, condiments and vegetables since the commencing of civilization (MacNeish 1964). Green fruits of chili are used as vegetable. On the other hand, ripe dried fruits as spice because of its pungency and imposing flavors (Hasan et al. 2014). It is inseparably involved with almost every kitchen in Bangladesh and its demand is increasing day by day due to its pungency, appealing color and flavor (Hasan et al. 2015). Many cultivars are grown in Bangladesh differing in habit, size, shape, color, yield, pungency of the fruit and preference of customer. In 2013, global production of chilli pepper (both green and dried) was 34.6 million tonnes with 47% of output coming from China alone. India is the top producer of dry peppers, producing 1.4 million tones (FAOSTAT 2012). In Bangladesh, average yield and production was 1.46 t ha^{-1} and more than 3 lakhs t ha^{-1} during 2014-2015, respectively (BBS 2015), which is lower than India and China.

The pungency of chili is due to capsaicin ($C_{18}H_{27}NO_3$), which has a great medicinal value. The 'capsaicin' is an alkaloid present in the placenta of the fruit, which can directly reduce various free radicals (Reddy and Lokesh 1992; Kogure et al. 2002; Bhattacharya et al. 2010) and has diverse prophylactic and therapeutic uses in Allopathic and Ayurvedic medicine (Sumathy and Mathew 1984). The applications of capsaicinoids in pharmaceuticals are attributed to its antioxidant, anticancer, antiarthritic and analgesic properties (Prasad et al. 2006). Chili is a good source of vitamin C (ascorbic acid) used in different food and beverage industries (Bosland and Votava 2000), vitamin A, vitamin B6, vitamin K and minerals like calcium, magnesium, folate, potassium, thiamin, iron, copper ctc. It has also attained a great importance because of having 'oleoresin', which permits better distribution of color and flavor in foods.

CHILI AS FUNCTIONAL FOOD

Functional foods are those food materials which have nutritional substances and play one or more important target functions in the body in reducing or minimizing the risk of

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certain diseases and improve health condition. A functional food must elucidate its potential in amounts that can ordinarily be expected to be consumed in the diet (Antonio et al. 2006). Capsaicin is the main bioactive plant compound in chili, responsible for their incomparable pungent taste and various health benefits. Capsaicin is considered a safe and effective topical analgesic agent in the management of arthritis pain, herpes zoster-related pain, diabetic neuropathy, mastectomy pain, headaches and lowers blood sugar levels, heal intestinal problems, improves heart health and protects against strokes. A number of study on human found that capsaicin has the potential to kill prostate cancer cells (Díaz-Laviada 2010). Other bioactive compounds such as Lutein, Sinapic acid, Ferulic acid, Violaxanthin etc. are present in Chili. In this respect chili, for the presence of capsaicin and other known active principles, can be regarded as a functional food. The consumption of hot red chili pepper reported to be associated with reduced mortality. Hot red chili peppers may be a beneficial component of the diet (Chopan and Littenberg 2017).

NUTRITIONAL VALUE OF CHILI

Fresh green and red chilies are great source of vitamin C. Chili contains good amount of other antioxidants such as vitamin A, B-complex group of vitamins such as niacin, pyridoxine (vitamin B6), riboflavin and thiamin (vitamin B1) and flavonoids like β-carotene, α-carotene, lutein, zea-xanthin, and cryptoxanthin. Chili also carries different minerals like potassium, manganese, iron, and magnesium. Nutritional composition of 100 g peppers in the form of raw green, raw red and spices or cayenne are shown in Table 1 to 7.

Table 1. Calorie information

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Calories	40.0 (167 kJ)	18.0 (75.4 kJ)	16.7 (69.9 kJ)
Carbohydrate	33.4 (140 kJ)	14.3 (59.9 kJ)	7.0 (29.3 kJ)
Fat	1.7 (7.1 kJ)	1.7 (7.1 kJ)	7.6 (31.8 kJ)
Protein	4.9 (20.5 kJ)	2.1 (8.8 kJ)	2.1 (8.8 kJ)

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)

Table 2. Composition of fats and fatty acids

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Total fat	0.1 g	0.2 g	0.9 g
Saturated fat	0.0 g	0.0 g	0.2 g
Monounsaturated fat	0.0 g	0.0 g	0.1 g
Polyunsaturated fat	0.0 g	0.1 g	0.4 g
Total omega-3 fatty acids	2.3 mg	5.0 mg	34.6 mg
Total omega-6 fatty acids	46.8 mg	103 mg	405 mg

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)

Table 3. Composition of carbohydrates

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Total Carbohydrate	4.3 g	4.0 g	3.0 g
Dietary fiber	0.7 g	0.7 g	1.4 g
Sugars	2.3 g	2.4 g	0.5 g

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)

Table 4. Composition of protein and amino acids

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Protein	0.9 g	0.8 g	0.6 g
Tryptophan	11.7 mg	11.7 mg	-
Threonine	33.3 mg	33.3 mg	-
Isoleucine	29.3 mg	29.3 mg	-
Leucine	47.3 mg	47.3 mg	-
Lysine	40.0 mg	40.0 mg	-
Methionine	10.8 mg	10.8 mg	-
Cystine	17.1 mg	17.1 mg	-
Phenylalanine	27.9 mg	27.9 mg	-
Tyrosine	18.9 mg	18.9 mg	-
Valine	37.8 mg	37.8 mg	-
Arginine	43.2 mg	43.2 mg	-
Histidine	18.4 mg	18.4 mg	-
Alanine	36.9 mg	36.9 mg	-
Aspartic acid	129 mg	129 mg	-
Glutamic acid	119 mg	119 mg	-
Glycine	33.3 mg	33.3 mg	-
Proline	39.1 mg	39.1 mg	-
Serine	36.0 mg	36.0 mg	-

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)
Note: Each "-" indicates a missing or incomplete value.

Table 5. Composition of different vitamins

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Vitamin A	530 IU	428 IU	2185 IU
Retinol	0.0 mcg	0.0 mcg	0.0
Retinol activity equiv.	26.5 mcg	21.6 mcg	109
α-Carotene	10.4 mcg	16.2 mcg	0.0
β-Carotene	302 mcg	240 mcg	1146
β-Cryptoxanthin	22.5 mcg	18.0 mcg	328
Lycopene	0.0 mcg	0.0 mcg	0.0
Lutein + Zeaxanthin	326 mcg	319 mcg	691
Vitamin C	109 mg	64.7 mg	4.0
Vitamin E (α-Tocopherol)	0.3 mg	0.3 mg	1.6
Vitamin K	6.4 mcg	6.3 mcg	4.2
Thiamin	0.0 mg	0.0 mg	0.0
Riboflavin	0.0 mg	0.0 mg	0.0
Niacin	0.4 mg	0.6 mg	0.5
Vitamin B6	0.1 mg	0.2 mg	0.1
Folate	10.4 mcg	10.4 mcg	5.6
Food folate	10.4 mcg	10.4 mcg	5.6
Folic Acid	0.0 mcg	0.0 mcg	0.0
Dietary folate equiv.	10.4 mcg	10.4 mcg	5.6
Vitamin B12	0.0 mcg	0.0 mcg	0.0
Pantothenic acid	0.0 mg	0.1 mg	-
Choline	5.0 mg	4.9 mg	2.7
Betaine	-	-	-

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)
Note: Each "-" indicates a missing or incomplete value.

Table 6. Composition of minerals

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Calcium	8.1 mg	6.3 mg	7.8 mg
Iron	0.5 mg	0.5 mg	0.4 mg
Magnesium	11.2 mg	10.4 mg	8.0 mg
Phosphorus	20.7 mg	19.4 mg	15.4 mg
Potassium	153 mg	145 mg	106 mg
Sodium	3.2 mg	4.0 mg	1.6 mg
Zinc	0.1 mg	0.1 mg	0.1 mg
Copper	0.1 mg	0.1 mg	0.0 mg
Manganese	0.1 mg	0.1 mg	0.1 mg
Selenium	0.2 mcg	0.2 mcg	0.5 mcg
Fluoride	-	-	-

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)
Note: Each "-" indicates a missing or incomplete value.

Table 7. Composition of other constituents

Constituents	Green chili, raw	Red chili, raw	Spices, red or cayenne
Cholesterol	0.0 mg	0.0mg	0.0 mg
Alcohol	0.0 g	0.0 g	0.0 g
Water	39.5 g	39.6 g	0.4 g
Ash	0.3 g	0.4 g	0.3 g
Caffeine	0.0 mg	0.0mg	0.0 mg
Theobromine	0.0 mg	0.0mg	0.0 mg

Source: modified from USDA National Nutrient Database (https://www.ars.usda.gov)

USES OF DIFFERENT PARTS OF CHILI

Chili peppers have been a part of human diet from yore. Different part of chili such as fruit, leaf and seed are used in medicinal purpose as well as in preparation of various food items.

Leaves of Chili

Chili pepper leaf is used extensively in preparing different medicines and food. The leaves of all species of Capsicum are edible. Though almost all other Solanaceous crops contain toxins in their leaves, chili peppers do not. The piquancy of chili leaves are mildly bitter but somewhere near as hot as the fruit (Pawar et al. 2011).

Medicinal use

The leaves of chili pepper contain capsaicin which has enzymatic synthesis and anti-obese properties, stimulates immune system and reduces blood pressure (Shimoda 2009). Capsaicin induces death of cancer cell in mice and even helps start producing insulin again in pancreatic cells in cases of type-2 diabetes (Kwon 2013). It also contains antioxidant which reduces cancer risk, cataracts, cardiovascular diseases and macular degeneration.

Culinary use

The leaves of chili are used in preparing delicious dishes in different food culture. The leaves are mildly bitter in taste but in some species it is nearly hot as the fruit (Dubey 2010; Sarkar et al. 2015). In Philippine recipe ingredients, it is called dahonngsili (literally "chili leaves") and used in the chicken soup Tinola. The leaves may be used in a traditional fermented Korean side dish made of vegetables with a variety of seasonings called kimchi. In Japanese cuisine, the leaves are cooked as greens, and also cooked in tsukudani that can be preserved and has been favored as a storable side dish.

Fruits of Chili

Green chili

Hot green chilies are used in almost every cuisine as spice and sweet peppers are used as vegetable salad in Bangladesh. Green chilies are used in preparing all delicious dishes such as chili chicken, chili paneer, chili sauce etc. (Takeda et al. 2008). It can enhance the flavor and taste of any food. Green chilies are rich in vitamin C which is strong antioxidant that strengthens natural immunity to diseases and vitamin A which is a fat soluble vitamin and an important antioxidant help to decrease the health hazards caused by free radicals. Vitamin A helps with the synthesis of red blood cells and is an essential component of rhodopsin, the protein that allows retinal receptors in the eye to absorb light. Green chili peppers are also rich in vitamin E that is essential for producing certain natural skin oils and prevents early ageing of skin. Green chilies have been linked with a lowered risk of having lung cancer, stomach cancer, prostate cancer (Diaz-Laviada 2010).

Red chili

Red chili produces phytochemical called capsaicin and it is used as spice and medicine (Columbus 1987). Capsaicin of red chili has pungent active principle that has been shown to cause gastric mucosal swelling and hyperemia and decrease in the gastric acid output (Desai et al. 1977; Nopanitaya 1973). Capsaicin helps in the metabolism of epoxide aromatic hydrocarbons, which intervenes with their ability of bind to DNA (Suzuki and Iwai 1984). It is also reported that red pepper have anti-obesity, analgesic and anti-inflammatory effects in animals and humans due to the capsaicin (Kwon 2013).

Seeds of Chili

Chili seeds are used to produce essential oil and its aroma is, not surprisingly, hot and spicy. It has wonderful therapeutic properties including the ability to speed up blood circulation, lower blood sugar, beneficial for healing wounds and to increase hair growth by delivering vital nutrients to the scalp. Chili seed essential oil is also used as a powerful pain reliever in joint and muscle aches, especially those caused by arthritis and migraine (Jarret et al. 2013). Psychologically, chili seed essential oil is used to create feelings of joy because the scent is so strong, it is best when diluted with other essential oil to create an original scent with unique properties.

MEDICINAL AND HEALTH BENEFITS

Anti-inflammatory

Chili peppers contain a phenolic compound capsaicin (8-methyl-N-vanillyl-6-nonenamide), which is characteristic component of pungency. Capsaicin is a potent inhibitor of substance P, a neuropeptide associated with inflammatory processes (Colpaert 1983). It reduces the inflammation by stimulating the blood flow to that site. Capsaicin is being an effective treatment for sensory nerve fiber disorders, including pain associated with arthritis, psoriasis, and diabetic neuropathy. When animals injected with a substance that causes inflammatory arthritis were fed a diet that contained capsaicin, they had delayed onset of arthritis and also reduced paw inflammation (Zayachkivska 2005). The contents of flavonoids and total phenolic compounds could be correlated with the antioxidant and anti-inflammatory activities observed for *Capsicum baccatum*. The butanol extract obtained from the

fruit of *Capsicum baccatum* presented the best antioxidant and anti-inflammatory activities. In this sense, *Capsicum baccatum* has potential antioxidant and anti-inflammatory compounds which could be used as prototypes in medicinal chemistry (Zimmer 2012).

Natural Pain Relief

The American Academy of Neurology clinical practice guideline states that the degree of pain relief from topical capsaicin is below the level considered clinically important for the treatment of chronic pain (AAN 2009). A systematic review of studies of herbal therapies for nonspecific lower back pain found moderate evidence of short-term effect for topically applied capsaicin, either as a cream or plaster, in reducing pain and improving function (Gagnier 2006). It was found in rheumatoid arthritis that capsaicin performed better than placebo in reducing pain (Little 2001). Capsaicin cream (either 0.025% or 0.075%) was effective when it is applied topically in the management of post herpetic neuralgia (Bernstein 1987). It has been evaluated in the management of pain from other causes, including trigeminal and diabetic neuralgia, osteoarthritis, postsurgical neuralgias (Altman 1994) and vulvar vestibulitis (Steinberg 2005). The side effect reported with topical capsaicin cream is a burning sensation at the area of application.

Cardiovascular Benefits

Red chili such as cayenne, have potentiality to reduce blood cholesterol, tri-glyceride levels, and platelet aggregation, while increasing the ability of body to dissolve fibrin, a substance integral to the formation of blood clots (Payan 1984). Cultures where hot chili is used in regular diet have a much lower blood pressure and rate of heart attack, stroke and pulmonary embolism (Wead 1987). Spicing meals with chili peppers may also prevent the deposition of fats in blood vessel walls caused by free radicals – a first step in the development of atherosclerosis (Ahuja 2006).

Boost Immunity

Red chili peppers of bright color indicating high content of β-carotene or pro-vitamin A and green chili contains high amount of vitamin C which strengthen the immune system of the body. Vitamin A often called the anti-infection vitamin is essential for healthy mucous membranes, which line the nasal passages, lungs, intestinal tract and urinary tract and serve as the body's first line of defense against invading pathogens. Active ingredient of chili capsaicin also boosts defense mechanism of the body (Payan 1984).

Stop the Spread of Prostate Cancer

Capsaicin is the major component in red chili which is responsible for pungent heat stops the spread of prostate cancer cells through a number of mechanisms. Capsaicin triggers suicide in both primary types of prostate cancer cell lines, those who's growth is stimulated by male hormones and those not affected by them. In addition, capsaicin extenuate the expression of prostate-specific antigen (PSA), inhibits the ability of the most potent form of testosterone, dihydrotestosterone, to activate PSA, and directly inhibits PSA transcription, causing PSA levels to plummet (Akio Mori 2006).

Prevent Stomach Ulcers

A notion among the people that excessive consumption of red chili leads to "gastric ulcers" due to its irritant and likely acid secreting nature. However, investigations carried out in recent years have transpired that "capsaicin" is not the cause for ulcer formation rather it help to prevent the infection of the stomach with *Helicobacter pylori* which has been found to be the main cause of gastric ulcers. Capsaicin does not excite but inhibits acid secretion. It stimulates alkali, mucus secretions and particularly gastric mucosal blood flow which help in prevention and healing of ulcers. Capsaicin acts by stimulating afferent neurons in the stomach and signals for protection against injury causing agents (Satyanarayana 2006).

Lower Risk of Type 2 Diabetes and Obesity

If the meal contains chili pepper could help quash the risk of hyperinsulinemia (high blood levels of insulin) a disorder associated with type 2 diabetes. When chili is a regular part of the diet, insulin requirements drop even lower and beneficial effects of chili on insulin needs get even better as body mass index (BMI, a measure of obesity) increases. In obese people, not only do chili-containing meals significantly lower the amount of insulin required to lower blood sugar levels after a meal, but chili-containing meals also result in a lower ratio of C-peptide/ insulin, an indication that the rate at which the liver is clearing insulin has increased (Kiran et al. 2006). Besides capsaicin, chilies also contain antioxidants, including vitamin C and carotenoids, which might help to improve insulin regulation (Ahuja et al. 2006). A little chili pepper can really cheer up an omelet, add heat to a black bean/sweet potato soup, or transform an ordinary salad dressing.

Prevents Sinusitis and Relieves Congestion or Anti-rhinitis Agent

Anti-rhinitis agent is an ingredient of nasal sprays effective in sinus problem like allergic rhinitis. (Bernstein et al. 2011). Capsaicin has capacity to tackle nasal congestion by helping clear mucus from nose. It also has antibacterial properties as well, and can help fight against chronic sinus infections (Ahuja and Ball 2006). It opens sinus passage releasing allergens from the nose by anti-inflammatory activity. Eating of green chili increases the nasal secretion and thus provides relief from congested nose.

Aromatherapy and Cosmetic Applications

Chili seed essential oil is derived from the steam distillation of hot pepper seeds which is semi viscous dark orange or red color oil is also known as *Capsicum oleoresin*. Chili seed essential oil is suitable for aromatherapy and also suitable to cosmetic applications, personal care formulations, soaps, perfumery, incense, candles. (https://www.jadebloom.com).

INTERNATIONAL TRADE OF CHILI

The world chili production is primarily concentrated in South Asian countries. India alone is the largest producer as well as exporter of chili. According to FAOSTAT, Food and Agriculture Organization of the United Nations during 2004-2013, India produced average 1238084.1 ton dry chili which was higher than china (261934.2 ton) and Thailand (156877.4 ton) and also produced 14214800 ton green chili which was also higher than Mexico (1975819.7 ton) and Turkey (1892725.6 ton). India was exported average 221425.2 ton dry chili followed by China with 97787.3 ton, Peru with 47193.5 ton, Spain with 31611.1 ton and Malaysia with 22383.1 ton which nearly half of the world's consumption demand. Rest of exports were scattered across a number of countries each contributing in minor quantities. Major importers of dry chili include the U.S. imported about 102345.9 ton followed by Malaysia with 75107.8 ton, Thailand with 39321.8 ton, Sri Lanka with 34932.5ton and Spain with 33262.3 ton. Interestingly, Spain was the fourth largest exporter but the fifth

largest importer as well. In case of green chili the largest exporter country was Mexico exported average 605484 ton followed by Spain with 464452.2 ton, Netherlands with 404548.8 ton, US with 100820.3 ton and Israel with 96633.4 ton. The largest importer of green chili was US imported average 668522.9 ton, followed by Germany with 316149.5 ton, UK with 150515.8 ton, France with 134363.5 ton and Canada with 111205.6 ton. From this above data, it indicates that the global trade of chili is greatly depends on India and China.

CHILI PRODUCTION AND PROSPECTS

Chili is one of the essential and important spices crops in many countries of the world. It grown commercially as spice-cum vegetable crop in India, China, Ethiopia, Hungary, Indonesia, Japan, Spain, Mexico and other countries. India is the largest producer of chili in the world, which is grown in an area of 9.15 m ha with production of 11 lakh tonnes. India accounts for 26% of global production followed by China. According to FAOSTAT, the production of dry chili in Bangladesh during 2004-2013 was 136788.27 ton which is very low compared to India (1238084.1 ton) and China (261934.2 ton). In 2013 Bangladesh was exported 312 ton and imported 28863 ton dry chili which shows a large amount of chili were to be imported to require the domestic demand. The production of chili is largely depends on different types of inputs such as high yielding variety, fertilizer, irrigation, pesticide etc. Cost of production of crops and market price of crops are directly interrelated. Sometimes market price is lower than the production cost, producers get looser and discouraged to produce more crops and if market price is higher than the production cost, producers get profit and encouragement. This type of loss and profit influence positively or negatively on the cultivation of chili. Chili production can be increased by giving subsidy to the farmers on different inputs and providing seeds high yielding variety. Demand for chilies and its products continue to increase in many parts of the world as chilies (*Capsicum* spp.) are a good source of beneficial compounds. Chili has high potentiality in export and different product of chili becoming popular day by day because of its highly nutritious value, taste and flavor.

CONCLUSION

Chili may be contraindicated to patients who are hypersensitive to chili or its product. Care should be taken when handling with chilies because it may irritate or burn the eye and skin. Excessive consumption of chili may toxic as we all know too much of anything can be bad. Chili can grow all year round. But the main consideration to make the chili production profitable is to increase yield and reduce production costs. This can be achieved by maximizing yield and quality through correct growing and harvest practices, and appropriate processing and storage. Number of pests and diseases can cause problems for chili production and reduce yield and quality. The overall best practices for chili production should be practiced.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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