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Chemical Composition, Nutritional, Medicinal And Functional Properties of Black Pepper: A Review

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Abstract

Black pepper is one of the important spice rich in aromatic and medicinal components along with appreciable levels of several other functional components having health promoting properties. The uses of black pepper in various fields such as food processing, pharmaceutical industry etc, is increasing steadily due to its recognition as an important source of natural antioxidant having anti-carcinogenic activity. It also have bioavailability enhancement nature, carminative property, anti-inflammatory action, cholesterol lowering capacity, immune enhancer ability, anti-pyretic, anti-periodic, antimicrobial and rubefacient activity. On searching out in past two decades research work it was found that there is scarcity of information on assessment of nutritional, medicinal and functional properties of black pepper and on the other hand, to perform the comparative study of ambient and cryogenic ground black pepper to asses in change in its all above mentioned properties such comprehensive study is required. The present review highlights the nutritional composition, medicinal properties, functional properties, product development and its utilization along with potential application. These finding will help to improve the output and final product quality of black pepper seed powder. The conclusion of this review have a broad impact across a wide range of industries such as food processing, pharmaceutical industry, medical field, health and nutrition as well as in academic field also.

Keywords: Aroma; Cryogenic; Piperine; Pungency; Volatile

Introduction

Spices are natural food additives which contribute immensely to the taste of our foods. From ancient times they have been used to enliven our foods. Spices possess medicinal as well as nutritional based properties. They have been effectively used as a one of the most important constituents in the medical field worldwide. They have beneficial influence on lipid metabolism efficacy as anti-diabetics. They have ability to stimulate digestion and; have antioxidant (Table 1) and anti-inflammatory (i.e., reduces painful swelling caused by tissue injury) potential [1]. Keeping in mind the potency of spices for medicinal and nutritional uses black pepper was selected and reviewed for its nutritional and medicinal value. The Table 2 shows the scientific classification of black pepper classification system.

Black pepper is the dried unripe berries and it gives peppercorn. Peppercorn is dried fruit which has not reached full ripening stage and it is main part which is communicated and used as spice and seasoning. In common language peppercorn is referred as black pepper. Peppercorn is the most consumable part of pepper plant. Black pepper is almost mature complete berry that is dried and separated from their stalks. It is an angiosperms and a climbing type flowering vine.

Ascorbic-acid	**0–10 ppm**
Beta-carotene	0.114–0.128 ppm
Camphene	
Carvacrol	
Eugenol	
Gammaterpinene	
Lauric-acid	400–447 ppm
Linalyl-acetate	
methyl-eugenol	
myrcene	
myristic-acid	700–782 ppm
myristicin	
palmitic-acid	12,200–13,633 ppm
piperine	17,000–90,000 ppm
terpinen-4-ol	
ubiquinone	

Table 1: Antioxidant active chemicals isolated from black pepper.

Compounds Responsible for Odor, Aroma and Pungency in Black Pepper

The aroma and odor are the most critical and central requirement

Kingdom	**Plantae**
Division	Manoliophyta
Class	Magnoliopsida
Order	Piperales
Family	Piperaceae
Genus	*Piper*
Species	*nigram*

Table 2: Taxonomical Classification of black pepper.

Chemical compound	Type of odor
α–terpineol	Floral
Acetophenone	Irritant, sharp
Hexonal	Green apple
Nerol	Fresh, Floral, Herbal
Nerolidol	Mild spicy, Rooty
1, 8 – cineol	Camphory
Dihydrocarveol	Warm, Woody
Citral	Citrussy
α–pinene	Terperic, Oxidised
Piperolnol	Sweet, Floral

Table 3: Major chemical compounds responsible for the aroma, pungency and medicinal property of the black pepper.

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for any spice and they are combinations of many compounds; in particular for black pepper major compounds responsible for the color, odor and aroma are shown in the (Table 3) which are found out from GCMS analysis [2]. It contains lignans, alkaloids, flavonoids, aromatic compounds and amides [3]. It also contains essential oil up to 3.5% and this oil constitutes sabinene, pinene, phellandrene, linalool and limonene. It also has piperine which is a weak basic substance. Chavicine is an isomer of piperine [4]. Piperine and Chavicine are not responsible for the aroma of the black pepper but piperine imparts pungency to the black pepper [5]. Table 4 shows the major medicinal and nutritional contents of black pepper [6].

Pharmacological, Toxicological, Clinical Applications and General Uses

Pepper is described as a drug which increases digestive power,

Variety	Pedigree	Yield (dry) kg/ha)	Piperine (%)		Oleoresin (%)		Essential oil (mg/100 g)	Phenols (mg%)		Free amino acids (mg%)		Starch (mg%)		Total carbohydrate (mg%)		Protein (mg%)	
			Leaves	Berry	Berry	Leaves	Berry	Leaves	Berry	Leaves	Berry	Leaves	Berry	Leaves	Berry	Leaves	Berry
Panniyur 1(KAU)	Hybrid between Uthirankotta xCheriyakaniakadan	1242	0.0004	2.8	8.5	0.12	2.4	0.8	0.5	0.4	0.4	1.5	34.1	2.6	38.6	1.25	5.2
Panniyur 2(KAU)	Selection (Cul. 141) from cv.																
Balancotta	2570	0.002	3.1	8.5	0.1	3.2	0.7	0.5	0.5	0.4	1.4	36.0	3.0	40.2	1.6	4.3	
Panniyur 3(KAU)	Hybrid (Cul. 331)																
Uthirankotta x Cheriyakaniakadan	1953	0.002	1.8	6.8	0.1	3.2	0.7	0.4	0.9	0.3	0.5	32.1	1.6	37.3	1.8	2.1	
Panniyur 4(KAU)	Selection from Kuthiravally Type	1277	0.001	3.8	11	0.2	5.0	0.5	0.5	0.9	0.5	1.8	43.2	3.9	49.3	1.0	2.3
Panniyur 5(KAU)	Open pollinated progeny																
selection from Perumkodi	1098	0.0003	3.6	9.5	0.2	2.8	0.6	0.6	0.6	0.3	1.7	42.0	3.5	46.2	1.2	3.5	
Panniyur 6(KAU)	Clonal selection from Karimunda	2127	0.00006	3.6	8.6	0.2	2.6	0.5	0.6	0.3	0.4	0.8	41.1	3.2	44.2	1.9	4.6
Panniyur 7(KAU)	Open pollinated progeny selection																
from Kuthiravally	1410	0.0003	3.5	8.7	0.2	2.6	0.6	0.7	0.5	0.3	1.1	43.2	2.9	51.2	1.5	2.1	
Subhakara (IISR)	Selection from Karimunda (KS-27)	2352	0.0005	4.0	13.9	0.2	6.0	0.3	0.6	0.3	0.3	1.4	42.7	4.8	46.4	2.3	4.3
Sreekara (IISR)	Selection from Karimunda (KS-14)	2677	--	4.2	9.6	0.2	4.0	0.7	0.6	0.3	0.3	1.8	42.2	2.8	45.1	2.8	3.6
Panchami (IISR)	Selection from Aimpiriyan (Coll. 856)	2828	0.001	4.1	10.5	0.2	2.8	0.5	0.5	0.3	0.4	1.2	36.0	3.2	39.2	2.4	3.7
IISR Thevam	Clonal selection of Thevamundi	2481	0.0008	1.6	8.2	0.3	2.8	0.6	0.5	0.4	0.3	1.5	35.1	2.6	38.6	1.2	3.3
IISR Girimunda	Hybrid between Narayakodi x																
Neelamundi	2880	0.003	2.2	8.9	0.2	3.0	0.3	0.3	0.3	0.4	0.7	38.7	2.5	41	1.8	3.0	
Malabar excel	Hybrid between Cholamundi x																
Panniyur-1	1440	…	3.0	12	0.1	3.2	0.4	0.4	0.3	0.6	2.1	36.4	3.1	39.6	2.0	2.7	
Kottaram			trace	3.8	9.0	0.2	3.2	0.4	0.3	0.5	0.3	0.7	40.2	2.4	45.1	1.5	2.1
TMB IV					7.0	0.1	1.6	0.7	0.5	0.2	0.5	0.8	38.2	4.5	46	1.5	3.5
Neelamundi			0.008	2.0	10.2	0.3	3.5	0.9	0.4	0.7	0.8	0.6	37.1	2.1	40.2	1.9	4.1
Karimunda			0.002	3.7	9.3	0.2	4.0	0.5	0.5	0.3	0.6	0.8	35.3	2.6	40.1	1.3	5.1
Vally			0.008	2.0	5.9	0.2	2.6	0.8	0.5	0.5	0.6	1.7	38	3.7	40.6	1.3	5.2
Vattamunda			0.0003	3.1	8.6	0.2	2.5	1.2	0.5	0.7	0.4	1	40.1	3.1	44	1.1	6.0
Aimpirian			0.0006	3.3	6.9	0.2	2.4	0.9	0.5	0.7	0.4	0.9	39.2	3.3	45.8	1.2	3.6
Angamali			0.0003	3.0	7.3	0.3	2.8	0.6	0.5	0.9	0.5	0.6	33.5	3.6	39.4	1.8	4.3
Kalluvally			0.002	2.8	8.1	0.2	3.3	1.1	0.5	0.5	0.5	1.1	42.8	3.5	46.8	2.0	3.8
Kottanadan			trace	3.8	9.0	0.3	5.5	0.7	0.4	0.3	0.4	1.0	39.1	1.9	48.5	2.0	5.2
HP-785			0.001	2.4	7.2	0.3	3.2	1.2	0.4	0.3	0.5	0.7	33.5	3	39.6	1.4	3.7
HP-1117			0.0001	2.6	7.5	0.3	2.0	1.2	0.5	0.4	0.5	0.7	37.3	4.6	42.2	2.7	3.5
HP-846			0.0004	2.6	7.6	0.1	2.4	1.5	0.6	0.4	0.5	2	35	4.6	40.1	2.8	3.1

Table 4: Medicinal and nutritional constituents of black pepper [6].

improves appetite, cures cold, cough, diseases of the throat, intermittent fever, colic, dysentery, worms and piles (Table 5). It stimulates circulatory system. It possesses a broad spectrum antimicrobial activity. Analgesic (alleviate pain), antipyretic (reduces fever) and anti-inflammatory actions are described, with piperine having been shown to be one of the active compounds in such cases. A protective impact of black pepper on key liver enzymes has been noted. As evaluated based on the Ames test, in mutagenic and carcinogenic properties of pepper gave favorable results. The antioxidant capacity of pepper phenolic amides (Table 4) was shown to be superior to the synthetic moieties butylated hydroxytoluene, antioxidant synthetic food additive) and butylated hydroxyanisole, synthetic antioxidant consisting of a mixture of two isomeric organic compounds (Table 5).

Bioavailability Enhancement

Black pepper and its volatile oil are used in food and food items to aid a) Digestion b) Relieve gas c) Treat food poisoning d) Stomach chills e) Cholera f) Dysentery g) Vomiting caused by hypothermia. Unripe, fresh green berries are used in sauces and to flavor various savory dishes. Ayurvedic medicine uses pepper mixed with ghee (buttery type compound) to treat external problem, nasal congestion, sinusitis, skin eruptions, and epilepsy. Piperine increases the bioavailability of valuable phyto-chemicals present in food items and can boost the activity of biochemically active compounds contained in it. It promotes the rapid absorption of certain chemicals from the gastrointestinal tract, protecting them from being broken down by chemicals in the intestinal lumen and by enzymes that occur in the cells lining of intestines. Once the compound has entered the blood stream, piperine provides protection against oxidative damage with the help of liver enzymes. In this way black pepper enables us to reap optimum benefits from the medicinal phyto-chemicals found in other dietary spices. Black pepper's bioavailability enhancing properties makes it as one of the most important spices. It should add to recipes and meals as often as possible because it boosts the medicinal value of many spices and other foods. Piperine extracted from pepper is a bioavailability enhancer that allows substances to remain in cells for longer periods of time. The researchers concluded that piperine enhances the serum concentration, extent of absorption and bioavailability of curcumin in both rats and humans with no adverse effects. This means that a low dose of curcumin could have a greater effect in terms of health benefits when combined with piperine than a large dose of curcumin or turmeric would.

Carminative

Pepper has a high degree of the stimulating and carminative properties, causing a reflex flow of saliva, with increased secretion of gastric juice and improved appetite. Gastro-intestinal movements are augmented, with consequent eructation of gas and relief of colic. In sufficient doses, the peppers dilate the superficial vessels of the skin, causing a feeling of warmth, followed by diaphoresis and some reduction of temperature. On account of these properties they are much employed as condiments, especially in hot countries. The pathological condition in which such painful masses occur, also called piles and black pepper is used as remedy for hemorrhoids. An oleoresin of pepper is prepared by extraction with acetone and separation from piperine.

Anti-cancer

Increasing bioavailability of other anti-tumor spices, pepper dramatically increases their potency and effectiveness against cancer. Black pepper counteracts cancer development directly. Its principal phytochemical is piperine, inhibits some of the pro-inflammatory cytokines that are produced by tumor cells. In doing so it interferes with the signaling mechanisms between cancer cells, thereby reducing the chances of tumor progression. Pepper prevents chemical carcinogenesis by stimulating the xenobiotic biotransformation enzymes. The antioxidant properties of piperine and associated unsaturated amides play a preventive role in carcinogenesis. Dietary intake of natural antioxidants could be an important aspect of the body's defense mechanism against the degradative changes caused by mutagens. The essential oil constituents inhibits DNA adduct formation by xenobiotics. Hexane, water and alcohol extracts of pepper were tested for mutagenic capacity on Salmonella typhimurium strains TA 98 and TA 100 by Ames assay and the results indicated the non-mutagenic

Application/ Utility	Responsible components	Problem addressed	References
Analgesic	piperine		Stanley, 2001
Antipyretic	Piperine		Stanley, 2001, Srinivasan, 2005
Rubefacient			
Inhibits lipopolysaccharide induced inflammatory responses	Piperine		Bae GS et al., 2011
Intermittent fever, colic, dysentery, worms and piles	Piperine		Stanley, 2001
Cures cold cough, dyspnoea, diseases of the throat	piperine	Improves breathing, reduce cough	Stanley, 2001
Improves appetite	Piperine		Stanley, 2001
Increases digestive power	Piperine		Stanley, 2001
Antimicrobial activity	Piperine		Stanley, 2001
A protective impact upon key liver enzymes		Proper liver functioning	Stanley, 2001
Antioxidant	Pepper phenolic amides, phenolic acids and flavonoids	Prevent DNA damage, cells, control oxidative stress	Stanley, 2001, Agbor et al., 2006
Mutagenic and carcinogenic properties		Cancer	Stanley, 2001
Spice, Culinary applications	Fruits, peppercorn	Improves food quality	Agbor et al., 2006
Preservatives	Fruits, leaves	Prevent food spoilage	Agbor et al., 2006
Cosmetic industry	Peppercorn	Improves beauty	Agbor et al., 2006
Insecticides	Peppercorn	Natural insecticide	Agbor et al., 2006

Table 5: Pharmacological, toxicological and clinical applications and general uses.

effects of the extracts. The volatile oil and its constituents suppress the formation of DNA adducts with aflatoxin B1. Two minor constituents of pepper, safrole and tannic acid, are attributed with minor carcinogenic activity. In a tissue culture study using V-79 lung fibroblast cell lines, reported that piperine treated cell lines showed increased DNA damage compared to untreated ones. Piperine treatment lowered the activities of the enzymes glutathione-s-transferase and uridine diphosphate glucuronyl transferase indicating the cytotoxic potential. The in vivo formation of n-nitroso compounds from naturally occurring amines and amides contribute to the carcinogenic potential of certain foods and food additives. Piperine and other phenolic amides present in pepper are also known for their conversion to n-nitroso compounds in acidic conditions and hence treated as carcinogenic but it can be inferred that the presence of conjugated unsaturated system in the phenolic amide prevents the oxidation of the amide nitrogen to n-nitroso compounds to a large extent. Moreover, the essential oil constituents of pepper also contribute to its anti-carcinogenic potential preventing DNA damage. Investigations reveal both carcinogenic and anti-carcinogenic nature. However, pepper as such exhibited anti-mutagenic and anti-carcinogenic effects.

Natural Antioxidant

Antioxidant compounds in food items play important roles as health-protecting factors. Black pepper is a source of effective antioxidants [5]. Black pepper actually maintains and enhances the levels and efficacy of important antioxidant compounds. It contains several powerful antioxidants and is thus one of the most important spices for preventing and curtailing oxidative stress. In addition to their direct antioxidant properties, several of these compounds work indirectly by enhancing the action of other antioxidants. Black pepper minimizes oxidative stress caused by saturated fats in the food. The high levels of cholesterol and triglycerides associated with oxidative stress inhibit the efficacy of important antioxidants (eg. glutathione, superoxide dismutase, catalase, glutathione peroxidase, vitamin C and E). Oxidation is a leading cause for quality deterioration during processing and storage of muscle foods. When stored at refrigerated temperatures, lipids in meat oxidize and unsaturated fatty acids form hydroperoxides that are subsequently decomposed to secondary products, including malonaldehyde (MDA) and other carbonyl compounds that cause off-flavours [7]. The best way to overcome this problem is to use natural antioxidant (Table 1) which is obtained from plant origin because synthetic antioxidant has many side effects. Black pepper may be one of the best natural anti-oxidant to be used to prevent oxidation and off flavor in meat and its products. Suhaj [8] study showed the some of the major anti-oxidant of the black pepper. The free radical scavenging activity of the different fractions of pet ether extract of piper nigrem was observed in an increased manner in a concentration dependent manner [9].

Black Pepper as an Anti-Inflammatory Drug

Inflammation is complex biological response of vascular tissues to harmful stimuli, such as pathogens, damaged cells, or irritants and anit-inflammatory means something which reduces the human body inflammation and black pepper is one of such substance. Anti-inflammatory drugs make up about half of analgesics, remedying pain by reducing inflammation. It is found that piperine significantly inhibited the production of two important proinflammatory mediators, IL6 and PGE_2, in IL1β-stimulated human FLS. The inhibition of PGE_2 production is important due to its central role in triggering pain. In addition, MMP1 and MMP13 collagenases play dominant roles in RA and osteoarthritis because they are the rate-limiting components of the collagen degradation process. The significant inhibition of MMP13 expression is particularly important because it degrades a wide range of collagenous and non-collagenous extracellular matrix macromolecules and is remarkably active against collagen type II, the predominant collagen in cartilage. Piperine inhibits the expression of MMP13 in IL1β-stimulated FLSs. [5]. Piperine showed a significant inhibition of increase in oedema volume in a carragenin induced test. Piperine acted significantly on early acute changes in inflammatory process [10].

Cholesterol Lowering and Immune Enhancer

Pepper doesn't have cholesterol. It enhances digestion process by helping faster break down of larger fat molecules into easily digestible simple molecules and prevents the accumulation of fat in body. Black pepper exhibits immunomodulatory effect on human body. It is able of boost and supports the number and the efficiency of white cells and assists the body to raise a powerful defense against invading microbes and cancer cells. Lianzhong et al. [11] found that the analysis of component PN-IIa showed a different monosaccharide composition, which contained a significant proportion of galactose, arabinose, galacturonic acid and rhamnose; and PN-IIa did react with β-glucosyl Yariv reagent, which indicated that PN-IIa might be an arabinogalactan; and purified anti-complementary polysaccharides from *Piper nigrum* [12] is suggested as a supplement for immune enhancement.

Anti-pyretic

Ayurvedic, Yunani, Siddha and folklore medicines in India used pepper and pepper containing preparations for the treatment of intermittent fever, neuritis, cold, pains and diseases of throat are practiced in Pepper is also used as an anti-periodic in malarial fever and therefore it is claimed having analgesic and antipyretic properties. Analgesic and antipyretic actions of piperine have been experimented on rabbit and mice and found strong antipyretic effect on typhoid vaccinated rabbits at a dose of 30 mg/kg body weight. Singh et al. [10] reported that piperine gave a strong activity with an ED50 of 3.7 mg/kg on writhing method and 104.7 mg/kg on tail clip method.

Anti-Periodic and Rubefacient

It helps in get rid of frequent fever such as a malaria. It acts as stimulant. If we apply powder of pepper on our skin it get stimulated and become red. The berries are used externally as rubefacient in baldness and skin diseases. The berries are decocted and the solution is used as a mouthwash for toothache.

Black Pepper Improves Digestion and Promotes Intestinal Health

It has been found that piperine can increase absorption of selenium, vitamin B, beta-carotene and curcumin. It can improve digestion and stimulate the secretion from the taste buds and taste bud stimulation is a feedback loop for digestion process. It sends impulses to the stomach to increase digestive juices secretion (eg. Hydrochloric acid). These juices break down the protein in the stomach, improving ability for further digestion in the duodenum. Bile acids are important for fat digestion and absorption and pepper constituents stimulate bile acid production by the liver and its secretion into bile [1]. When the body's production of hydrochloric acid is insufficient, food may retains in the stomach for an extended period of time, leading to heartburn or indigestion, or it may pass into the intestines, where it can be used as a food source for unfriendly gut bacteria, whose activities produce gas,

irritation, or diarrhea or constipation. In addition, it has diaphoretic (promotes sweating) and diuretic (promotes urination) properties. This wonderful seasoning promotes the health of the digestive tract and not only does help to derive the most benefit from food, the outer layer of the peppercorn stimulates the breakdown of fat cells, keeping human slim while giving energy to work [13,14].

Processing Problem and Preservation of the Flavor Content

Black pepper mainly available in two different forms: a). Whole pepper b). Powder. While buying peppers, ensure that the variety purchasing is organically grown and not exposed to any form of radiations. Radiations causes decrease in the level of the vitamin C. The ideal way of storing peppers is keeping them in a tightly sealed container in a cool, dark and dry place. In this way, whole peppercorns can be kept for long period, while the fresh ones can be kept for a maximum of three months. It can also be stored by freezing it, but this will cause a substantial decrease in the flavor. While grinding care should be taken because its fine dust may cause nose burning, sneezing and coughing. Cryogenic grinding is a novel approach to grind the black pepper at low temperature so that its flavor, aroma, odor and natural taste can be retained. Excessive topical use of black pepper essential may over stimulate the kidneys.

Conclusion

Consumers are health conscience and they prefer natural food items which are free of synthetic additives, colorant, artificial adhesive. Black pepper is a spice which can provide natural nutritional and medicinal benefit. It has analgesic, antipyretic, anti-inflammatory, antimicrobial and antineoplastic properties. Piperine is the major alkaloidal constituent of pepper. Systematic pharmacological studies on piperine have revealed its analgesic, antipyretic, anti-inflammatory and central nervous system depressant activities. It improves digestion by stimulating the taste buds in such a way that an impulse is sent to the stomach to increase hydrochloric acid secretion. These surmised all information on medicinal and nutritional value assessment of black pepper will find its utility in academic field, scientific research and real world industrial application.

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