REVIEW

Value addition and nutritional enrichment of wonder food mushroom

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REVIEW

Value addition and nutritional enrichment of wonder food mushroom

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Mushroom is being considered to be one of the most important nutritional diets from ancient times. The presence of various potential bioactive components makes it valuable. Human needs and progressive scientific trends create the automated demands to make this cosmopolitan food more nutritious. Different metallic ions are essential for the growth and metabolism of various creatures, they can be toxic at the above concentration level. Metals like Pb, Cd, Hg and Li are toxic with direct consumption which are required in tracer amount in some biometabolic pathway, but can also accumulate by various mushrooms in biofortified form. The bioaccumulation potential of various nutritional components enriched with essential elements by fungi has been investigated in mushroom and found to be high absorption rate. Nutritional enrichment with Selenium (Se) and Lithium (Li) are found to be remarkable milestone for value addition in this food, because its takes an important role in biosynthesis of selenoenzymes and selenoproteins like as thioredoxin reductase, glutathione peroxidase, selenoprotein and iodothyronine deiodinase respectively. Presence of Selenium (Se) and Lithium (Li) in the food helps in multifunctional activities like antioxidant defense, immunomodulation, carcinogenesis prevention, anti-inflammation, thyroid functioning, detoxification and sperm motility and maturation, psychiatric disorder. Se-Li biofortified mushrooms can fight against various diseases like HIV infection, immunological disease, neurological disorder, cancer, cardiovascular diseases, early aging and hence considered as one of the potential dietary supplement, nutraceutical and functional food. Thus, the production of value-added products like mushroom and its several extract (powder, soup, beverages) can help unemployed youth, rural women, landless or small farmers and self-help groups for sustainable economical empowerment.

Key words: Bioaccumulation, mushrooms, nutraceuticals, value addition

INTRODUCTION

Mushroom is one of the most important nutritional diet from ancient times of food history and is a boon to human health (Barman *et al*. 2018) . Wide nutritional enrichment and unique delicious taste makes the food more popular throughout the globe.

Biosynthesis of selenoproteins and selenoenzymes in human body requires the compound selenium as one of the fundamental requirements. Nutraceutical and pharmaceutical aspect of mushrooms encompasses with carcinogenesis prevention, thyroid functioning, antioxidant defense, detoxification, anti-inflammation, immunomodulation and sperm motility and maturation. For the aforesaid reason 'Se' is consider to be one of the major dietary supplements for humans (Kora and Rastogi, 2017). Different metallic ions are essential for the growth and metabolism various creatures, they can be toxic at the above concentration level. Metals like Pb, Cd, Hg and Li are toxic with direct consumption which are required in tracer amount in some biometabolic pathway but can also accumulate by various mushrooms in biofortified form. Lithium is considered to be an alkylatic metal, whose dietary effects have been little investigated. Lithium is present in tracer amount in some specific vegetables and grains (Schrauzer, 2002). Nutritional enrichment with Selenium (Se) and Lithium (Li) are found to be remarkable milestone for value addition in this food, because its takes an important role in biosynthesis of selenoenzymes and selenoproteins like as thioredoxin reductase, glutathioneperoxidase, selenoprotein and iodothyronine deiodinase respectively. The increased concentration of Selenium can cause

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toxic to human body while at trace level act as a potential weapon against several health issues (Kora, 2018 a). The safer concentration of 'Se' for healthy adults ranges in between 70 and 400 µg/person/day. The concentration of Selenium also varies in fruits, fish and seafoods, vegetables .i.e 0.0062 to 0.089 µg/g, 0.56 to 2 µg/g, 0.017 to 0.12 µg/g respectively (Falandysz, 2008). The inorganic form of Se which are available commercially are sodium selenite (Na_2SeO_3), sodium selenate (Na_2SeO_4), selenium dioxide (SeO_2), sodium selenite (Na_2SeO_3), sodium hydrogen selenite ($NaHSeO_3$) and selenium radical (Se^0) (Kora 2018 a). Accumulation of lithium (Li) by *Pleurotus ostreatus* mushroom is well proved and the accessibility of Li residues compared to lithium carbonate (Li_2CO_3) is high which is used for preparing psychiatric medicines and many more medicines against critical neuromotor disorders. Alternative mushroom bed substrate like coffee husk showed greater absorptivity with different added concentrations of lithium chloride (LiCl). In generally, organic Se maximally present in seleno amino acids like as selenomethionine in phyto-food components and selenocysteine in non-vegan foods. Selenium residues recycling through food web from simplified vegetative resource to advance creatures like human beings. The Se contents in various food items differs such as bioavailability, composition of Se in water and soil, absorption, biotransformation and potentiality of organic or inorganic Se compounds (Falandysz , 2008). Selenium concentration on the soil surface estimated as below 0.7 mg/kg, and the seleniferous soils contain > 0.5-0.7 mg/kg. Mostly seleniferous soils enriched with Se residues ranged between 2.7 to 6.5 mg/kg in Indian perspective. In crop like mustard, wheat, rice and its derived products such as grain and husk, it varies from 13 to 670 mg/kg. Phyto-chemical analysis of rice leaves revealed that the Se residue ranges between 1.5 to 2.0 mg/kg (Sharma *et al*. 2014). In nutraceutical perspective, *P. ostreatus* mushrooms enriched with promising source of Li, though other mineral contents of this food source is limited. Biological efficiency (BE) and biochemical indexing reflects that the crude protein content and the concentration of Li with addition of some inorganic metallic residues are present in mushroom in tracer amount. Edible mushroom like *Pleurotus ostreatus* has the multi-dimensional nutraceutical approaches making them as one of the healthy foods. Inclusion of this mushrooms or its derived food products positively affect the lipid and antioxidant profile of hyper cholesteraemic patients (Hossain *et al*. 2003; Jayakumar *et al.* 2007). Additionally, it is also enriched with zinc (Zn), copper (Cu), iron (Fe), selenium (Se), and molybdenum (Mo), which are directly or indirectly involved in various biometabolic and biosynthetic pathway (Zaidman *et al*. 2005). The bioaccumulation potential of nutrients by mycelium and also in mushroom (enriched with essential elements) is more compare to other phyto-food based resources (Munoz *et al*. 2006; Rabinovich *et al*. 2007; Silva *et al*. 2012). The most important fact is that increasing world's population and their up-growing food demand makes re-cultivation of same cereal crop in the same field repeatedly which creates mineral imbalance in the soil and finally causes essential mineral nutrients scarcity in the diet (Johns and Eyzaguirre 2007). The elemental Lithium is also present in different types of mushrooms such as *Craterellus cornucopioides*, *Psathyrella candolleana, Amanita strobiliformis*, *P. ostreatus* (Vetter, 2005). Li is not considered as a crucial mineral for vital functions because very less symptomatic appearance for its deficiency has been reported (Schrauzer, 2002). The mechanistic approach of mind stabilization and its indirect interconnection with blood Li level was studied. It was also observed that GSK-3b (glycogen synthase kinase 3b) which is involved in the mechanical and physiological pathway of several psychiatric disorders is directly or indirectly blocked by Lithium. In one clinical trial carried out in rats, a direct connection between the content of serotonin and aggression was observed which seems to facilitate GSK-3b activity (Jope, 2003). Li also takes a crucial role in brain function. The circadian clock is also regulated by GSK-3b resulting the inability to reset the ''master clock'' of the human brain, which lead to the interruption of biological cycle. Interruption of biological cycle causes dysfunction in metabolism, sleep and body temperature and extended with many more symptomatological expressions (Mcclung, 2007).

With this summarized review, we are trying to focus on 'importance of Se-Li' as a crucial diet, appearance of various deficiency symptoms for the non-consumption of Li-Se based foods, need of Se-Li enriched mushrooms, methods of Se-Li enrichment in mushrooms, nutritional and antioxidant availability and its impact, spontaneous anticancerus property Se-Li biofortified

mushrooms'. Additionally, we are trying to focus light on Se-Li enriched mushroom as - functional food, antioxidant, diet supplements and nutraceutical under this review.

PROGRESS OF MUSHROOM RESEARCH IN INDIAN SCENARIO

Some economically important, edible, delicious mushroom species grown in different states of India named *Volvariella volvacea* (paddy straw mushroom), *Agaricus bisporus* (Button mushroom), *Pleurotus ostreatus* (oyster mushroom), *Calocybe indica* (milky mushroom) (Fig.1). Some other edible species are *Pleurotus sajor-kaju*, *Hypsizygne ulmarius*, *Pleurotus djamor* and *Lentinula edodes* is considered to be partly edible and partly medicinal. Indian progressive mushroom research started through 'All India Coordinated Research Project on Mushroom (AICRPM)' and with the establishment of ICAR-National Research Centre for Mushroom (ICAR-NRCM). Progressive development of mushroom research comes with the hand of ICAR-NRCM who served the duty for last 36 years with the standardization of various cultivation techniques, development of technology for superior strains, casing materials, supplements, application of safer chemicals for disease and pest management, utilization of diverse substrates, shelf-life improvement, post-harvest processing etc. Mushrooms are well known for their culinary, nutritional, pharmacognital and health benefits which increase the demands of mushroom cultivation across India (Ahlawat *et al*. 2008). Various kinds of proteins, phenolics, antioxidants and numerous vitamins (B, C, D, riboflavin, thiamine, nicotinic acid, folic acid, niacin) and multiple microelements (K, Fe, Zn, Cu, P) preserved in significant amount in Mushrooms. Sugars, sodium, cholesterol, fat, and calorific value are present in mushroom in tracer amount. In nutraceutical perspective "Na" present in very lesser amount compare to K, which are very much helpful for the patients who are suffering with hypertension, obesity, and diabetes. All the nutrient content remains same after food processing through high temperature or boiling. The aforesaid edible mushrooms are acts on multidimensional point of view like - antiviral, chemopreventive, hypolipidemic, antibacterial, antitumor, and immunomodulatory activities etc (Olga and Alla, 2017; Rodriguez Estrada *et al.* 2009).

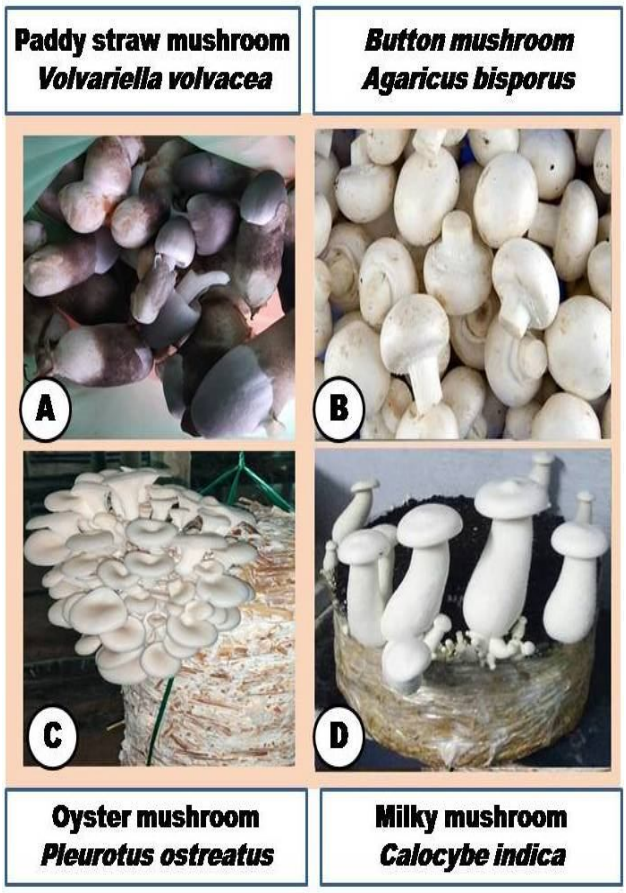

Fig. 1: A. *Volvariella volvacea* (paddy straw mushroom), **B.** *Agaricus bisporus* (Button mushroom) **C.** *Pleurotus ostreatus* (oyster mushroom) , **D.** *Calocybe indica* (milky mushroom)

NEEDS OF NUTRIENT ENRICHMENT

Selenium enrichment

Generally, most of the commercially cultivated grown mushrooms are deficient in selenium which ranges from < 1- 8.5 µg Se/g dry weight. However, most wild edible mushrooms are enriched with a good amount of selenium content which varies from 12-200 µg/g (Falandysz, 2008; Costa-Silva,2011; Kora, 2020). However, the wide scale cultivation of these wild mushrooms is not possible as they demand more sophisticated cultivation methods and lack proper environmental condition. Therefore, wide scale production of selenium fortified edible mushrooms can be the best way to increase the selenium content. The edible mushrooms increase the selenium content by accumulating it from various substrates containing organic or inorganic form of selenium. The absorption of selenium and protein from the substrate results into selenoenzymes or selenoproteins. Several organo selenium

Table 1: List of selenization methods reported in various edible mushrooms and the selenium concentration in substrate and fruiting body

Mushroom species	Amended Se form	Se load of substrate (µg/g)	Se concentration of fruiting body (µg/g)	Reference
Volvariella volvacea	Se- hyperaccumulated paddy straw	29.7	35	(Bhatia *et al*. 2014)
Calocybe indica	Na_2SeO_3	5	3.2	(Rathore *et al*. 2018)
Ganoderma lucidum	Na_2SeO_3	100-250	72	(Zhao *et al*. 2004)
Agaricus bisporus	Na_2SeO_3	4.6	30	(Prange *et al*. 2019)
Agaricus bisporus	Na_2SeO_3	10	0.3-2.8	(Prange *et al*. 2019)
Agaricus bisporus	Selenized yeast	10	770.7	(Gergely *et al*. 2006)
Agaricus bisporus	Selenized yeast	10	160	(Dernovics *et al*. 2002)
Pleurotus ostreatus	Se-hyperaccumulated wheat straw	24	44.3	(Bhatia *et al*. 2013)
Pleurotus ostreatus	Selenized yeast	25	42.4-50.2	(Savic *et al*. 2012)
Pleurotus sajor-kaju	Se- hyperaccumulated wheat straw	27	43.5	(Bhatia *et al*. 2014)
Pleurotus djamor	Na_2SeO_3	25.6	76	(Oliveira and Naozuka, 2019)
Pleurotus eryngii	Na_2SeO_3	5-10	4.6-9.3	(Rodriguez *et al*. 2009)

compounds such as selenocysteine, selenomethionine, selenomethylselenocysteine etc (Savic *et al*. 2009, Da Silva *et al*. 2012). From these, Selenium present in the form of selenocysteine and selenomethionine which act as, antioxidant, antimutagenic and anticancerous effective molecule. It was also observed that the biological activity of selenium is mostly determined by the chemical form and its dose (Kora, 2018 b).

Lithium enrichment

The deficiency of alkali metal, Lithium does not show any symptoms in human body, but affect the behavior without any physiological changes (Schrauzer, 2002; Vetter, 2005). This metal is also known to promote mood stabilization in humans. High dose of lithium enriched salts was prescribed by doctors to treat or prevent bipolar disorders (Marshall, 2015). But the side effects such as nausea, excess urination, confusion, agitation, myoclonic jerks etc made is an obsolete treatment in recent days. The mechanism of Li behind mood stabilization has also studies which showed that the Li ions inactivate the activity of GSK-3â (Glycogen synthase kinase 3â) involved in numerous psychiatric disorders. This metal Li and GSK-3â regulation can also affect the circadian clock resulting disturbances in sleep, metabolism and body temperature regulation (Jope, 2003 ; Mcclung, 2007). Generally, the concentration of Li is very low in commercially grown edible mushrooms. Most vegetables and grains are rich in Lithium. Several mushrooms such as *Pleurotus ostreatus, Amanita strobiliformis, Craterellus cornucopioides* etc also known for containing different concentrations of lithium. The concentration of Li in edible mushrooms directly depend on the Li enriched substrates from where it is absorbed. Many studies have also proved the easy accessibility and availability of Lithium from mushroom as compared to psychiatric drugs (Assunção *et al*. 2012).

METHODS OF NUTRIENT ENRICHMENT (Se-Li)

The concentration of selenium or lithium is directly proportional to the amount of these metals in substrate. The successful enrichment method also depends on the addition of Se source, its species and dose, physiology and biological efficiency of mushroom, content of selenoprotein, morphology of essential elements, their chemical characteristics, yield of biomass etc. (Cremades *et al*. 2012, Oliveira and Naozuka, 2019). The enrichment of Se can be done by applying either organic (selenized yeast) or inorganic (SeO_2, Na_2SeO_4, Na_2SeO_3) form of selenium directly to the substrate or irrigation water (Cremades *et al*. 2012, Oliveira and Naozuka, 2019). Similarly, cultivation of mushrooms on selenium accumulated agricultural residues such as wheat or paddy straw

grown on selenium rich soil can also be another way to increase the Se content in mushroom. Many studies have reported several selenization process on various edible mushroom and their substrate, content of accumulated Se in mushroom fruiting bodies which is listed in below Table -1. Research carried out by Savic and his co-workers showed that the enrichment of oyster mushroom (*Pleurotus ostreatus*) mainly depends upon chemical form of Se added in substrate. It was concluded that Na_2SeO_3 is more preferred and potential enrichment source as compared to other inorganic forms of Se (Savic *et al*. 2009). Similar studies on *Agaricus bisporus* have showed the fungus accumulated 3.1µg/g and 0.3-2.8µg/g of biomass when Na_2SeO_3 is added at a concentration of 100µg/mL and 10µg/g (Cremades *et al*. 2012; Stefánka *et al*. 2001). Similar type of studies was also conducted on milky mushroom (*Calocybe indica*) (Rathore *et al.* 2018), oyster mushroom (*Pleurotus ostreatus* and *Pleurotus djamor*) (Oliveira and Naozuka, 2019; Rodriguez *et al*. 2009; Milovanovic *et al*. 2019). When the *Pleurotus ostreatus* and *Pleurotus cornucopiae* were enriched with selenized yeast, the mushrooms were reported with an increased selenium content of 42.4-50.2 and 42.8µg/g respectively (Savic *et al*. 2012).

In India, wheat and paddy are main crops in northern and southern regions respectively. The post-harvest residues of wheat and paddy are major potential substrate to cultivate edible mushrooms like *Volvariella volvacea* and *Pleurotus* spp. One study was carried out to biofortify these 2 types of mushrooms where the substrates are grown priorly in seleniferous soil. It was reported an increased in Se concentration i.e., 35 µg/g in *V volvacea* and 43.5 µg/g *P sajor-kaju* which was very low in control. This study demonstrated the successful utilization of selenium hyperaccumulated agricultural post-harvest residues for production of Se-biofortified mushrooms (Bhatia *et al*. 2014).

ROLE OF Se-Li BIOFORTIFIED MUSHROOM

Nutritional and antioxidant entity

A large number of various antioxidants are present in mushroom such as phenolics, ergothioneine etc, which helps to release oxidative stress or indirectly creates a barrier against the development of various diseases. The present antioxidants participate in different biometabolic reactions and at the end produce free radicles (Rodriguez *et al*. 2009). The edible mushrooms contain low amount of Selenium (Se) and therefore marginal contribution towards Se intake through diet is needed (Costa-Silva *et al*. 2011). One of the remarkable points for Se biofortification of *P. ostreatus* (inorganic Se *.i.e.* Na_2SeO_3) with coffee husk substrate is that the fungi biomagnifies and absorbs Se (Da Silva *et al*. 2012). This enrichment method or process does not hinder any of the fungi functions such as their ability towards biodegradation of organic substrate or biological efficiency or degradation potentiality. Therefore, the bioaccessibility of other elements simultaneously increased such as Mg, P, S, Fe and Zn. With addition to that, Selenium accumulation can helps to produce potent selenoproteins (Oliveira and Naozuka, 2019). *In vivo* Selenium (Se) concentration level was checked in Wistar rats after feeding of *P. ostreatus* mushroom. Laterly comparison of Li level was checked. Results come with that total Se concentration was higher in case of biofortified Na_2SeO_3 food and this 'Selenium bio-fortified' mushrooms (if Se is in inorganic form) are more easily consumable by the humans. These can be considered as a vital subsidiary food source as it turned to more bio-consumable Se source like as selenoproteins. Explicit studies on various edible mushrooms like button, paddy straw and oyster grown on 'Se' fortified wheat and paddy straw, are the richest and toppest source of antioxidants, phenolics which transformed to 1, 1-diphenyl-dipicrylhydrazyl (DPPH) radical. Fortified DPPH has the property of scavenging, metal chelating and lipid peroxidation inhibition which found to be more effective than unfortified mushrooms (Bhatia *et al*. 2013, Bhatia *et al*. 2014). Naturally preserved organic Selenium (Se) present in Se-exopolysaccharides form which biosynthesize the desired level - 4.8 mg/g of Selenium such as SeIol presents in the medicinal mushroom *Hericium erinaceum*. The Se-EPS considered as a potential nutraceutical and dietary supplement (Malinowska *et al*. 2009). Similarly, the Se dose dependent radical scavenging action was observed in fungus *G. lucidum* which was superior than the polysaccharide extracts obtained from naturally grown *G. lucidum* (Zhao *et al*. 2008). Biofortification in *G. lucidum* found to be more effective where Se was transformed to water soluble Se containing protein with a scalable level of Se concentration

(4.8 mg/g protein). It was observed that *C. indica* cultivated on wheat straw soaked with inorganic Na_2SeO_3 (5-6 ìg/g), the fructifications transformed the inorganic Selenium to organic selenium or selenoproteins (55-70%) polysaccharides (22–29%), and nucleic acids (1.4–2.7%). At the post biofortification stage threonine and cysteine levels are also increased.

Lithium is considered to be one of the most effective crucial medications for treating bipolar disorder. Presence of Lithium can control severity and frequency of mania. Additionally, it helps to relieve or prevent bipolar depression. Prolonged studies revealed that Lithium can reduce suicide risk. In another way it is proved that Lithium can prevent future manic and depressive episodes. Therefore, Lithium based products used for long time as maintenance therapy. Lithium has a crucial role in person's central nervous system (brain and spinal cord). The mechanism still under cover that how lithium works to stabilize a person's mood, but it conceptualized that it helps strengthen nerve cell connections in brain regions that are involved in regulating thinking ability, mood and behavior. Lithium starts working in human body within few weeks. It is also found decreased lithium level in the human body can affect kidney or thyroid function. Lithium became more effective if the amount of the drug inside the human body is kept at a constant level. The most important fact is that in human body Lithium needs to present at a optimum balanced level, not too much or not too less. The dose of lithium varies among individuals from infant to adults. Although bipolar disorder is often treated various amount of drugs but significant amount of Lithium treatment also can control the disease. Imbalanced level of Lithium can causes many side effects like as increased thirst, vomiting, increased urination, diarrhea, weight gain, impaired memory, poor concentration, drowsiness, muscle weakness, hair loss, acne, decreased thyroid function etc. It is to be mentioned that at the time of lithium based medications consumptions special care needs to take about limit alcoholic beverages. Non-steroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen increases lithium levels for multidimensional purposes which can mitigates easily by biofortified Lithonoid based mushroom production.

Anticancerous property development

Prolonged study and based on review of literature it is proved that 'Se' supplementation in diet can moderate and block several stages of cancer such as initiation, promotion, and progression. More in depth researches revealed that female Sprague Dawley rats if fed with Se-fortified button (*A. bisporus)* mushroom they can produce potent anticarcinogen. Previous study reflects that nutritional enrichment with 'Se' biofortified white button mushrooms considerably triggered the activity of both liver and mammary glutathione S-transferase and extremely suppressed the DMBA-induced mammary epithelial cell DNA adducts. Experiments revealed that the dietary supplementation of biofortified Se enriched mushroom is very much effective to block tumors growth. Comparative analytical study reflects that cancer cell line A549 showed greater activity in case of 'Se' fortified edible mushrooms (like paddy straw, button, oyster, milky mushroom) than inorganic form. An elevated proliferation inhibition occurred in comparison with unfortified control mushrooms (Bhatia *et al*. 2014). Metastasis is mainly responsible for mortality in cancer patients. Although there are few numbers of anti-cancerous drugs available which are targeting tumor growth, anti-metastatic agents but very critical to develop the same. Angiogenesis and lymphangiogenesis both are very much important for cancer progression, specifically, lymphangiogenesis is progressive mechanism for metastasis in cancer. Lithium has the potentiality to inhibit colon cancer metastasis by blocking lymphangiogenesis. Lithium decreases the efficacy of transforming growth factor-â-induced protein (TGFBIp) in to colon cancer cells by complete blocking of Smad3 phosphorylation via GSK3â inactivation. Lithium ceased lymphatic endothelial cell migration, which is dominant upon TGFBIp activity in tumor cells. Lithium had no positive effect on SW620 which causes tumor growth in vitro and in vivo; however, it inhibited lymphangiogenesis in tumors. Different experimental results revealed that in tumor xenografts model, lithium was found more effective to control metastasis in the lungs, liver, and lymph nodes by blocking TGFBIp-induced tumor lymphangiogenesis. Summaively we can say the role of lithium for stopping colon cancer metastasis by acute inhibiting of TGFBIp expression which resulted with TGFBIp-induced lymphangiogenesis, in initial tumors growth.

Functional food, nutraceutical and diet supplement

The Se-biofortified mushrooms are regarded as novel functional food and dietary supplements due to their various nutraceutical characteristics. The selenium fortification increases its benefits such as anticancer and antioxidant activities. Inclusion of Se-fortified mushroom in regular diet system helps in prevention and treatment of various health issues such as cancer, aging, neurodegenerative disorders, cardiovascular and immunological problems, HIV infection etc. (Cremades *et al*. 2012). The mushrooms grown on selenized yeast or Se amended or hyperaccumulated substrate convert the Se in to less toxic and more bio-available form. It was found that approximately 86% of Selenium compounds are organic while nearly 73% of bio accessible are selenomethionine can be available for longer period of time (Olga and Alla, 2017 ; Witkowska, 2014). The recommended daily intake of Se is 70 µg/g, which can be fulfilled by consuming dietary supplement derived from aqueous enzymatic extract of selenized mushrooms or selenium enriched mushroom diet (Cremades *et al*. 2012 ; Zhao *et al*. 2004).

CONCLUSION

The unbalanced and unhealthy diet system is making many people to suffer from many diseases and disorders. Therefore, the need of the hour for the world is to think on the inclusion of healthy foods in regular diet system. As most of the vegetarian as well as non-vegetarians prefer mushrooms as one of the delicious and nutritious food, the biofortification of commercially grown edible mushroom and its wide scale production can make it possible. In countries like India where the substrates are easily available and abundant and the suitable climatic condition aids an opportunity for wide scale production of numerous varieties of biofortified edible mushrooms. Additionally, these Se-biofortified mushrooms are also generate more revenue in case of small and marginal farmers, rural women, unemployed youth, SHGs (self help groups) creating a sustainable empowerment climate. These biofortified mushrooms also serve as heterogenous value added products such as diet supplements, nutraceuticals and functional foods. However, the commercial production of Se-Li biofortified mushrooms are not adopted till now due to lack of proper knowledge and technology development such as methods of substrate amendment, proper dose and chemical and morphological characteristics of Se-Li compounds, biomass yield, organoleptic evaluation, cost effectiveness etc. In addition to this, the proper and safe disposal of spent compost, careful handling of volatile selenium compounds and selenium leaching in to soil with irrigation water during cultivation should be evaluated. Further studies are required to preserve and store of these biofortified mushroom for long days without losing the Se-Li content, toxicity and therapeutic dose for individual disease, accumulation of Se and Li in blood and tissues, pharmacodynamics of Se after consumption of Se-Li enriched mushrooms. Before marketing the biofortified mushrooms, the whole procedure should meet the required guidelines from regulatory agencies like FDA (food and drug administration).

REFERENCES

Ahlawat, O.P., Kumar, S., Arumuganathan, T., Tewari, R.P. 2008. 25 years of AICRP (mushroom). National Research Centre for Mushroom, (Indian Council of Agricultural Research), Solan, pp-1-95.

Assunção, L.S., da Luz, J.M., da Silva, M.D.C., Vieira, P.A., Bazzolli, D.M., Vanetti, M.C., Kasuya, M.C. 2012. Enrichment of mushrooms: an interesting strategy for the acquisition of lithium. *Food Chem.* **134**:1123–1127.

Barman, S., Chakraborty, B.N., Chakraborty, U. 2018. Edible mushroom: Boon to human health and nutrition. *J. Mycopath. Res*. 58:179-188.

Bhatia, P., Prakash, R., Prakash, N.T. 2013. Selenium uptake by edible oyster mushrooms (*Pleurotus* sp.) from selenium-hyperaccumulated wheat straw. *J Nutr Sci Vitaminol.* **59**:69–72.

Bhatia, P., Prakash, R., Prakash, N.T. 2014. Enhanced antioxidant properties as a function of selenium uptake by edible mushrooms cultivated on selenium accumulated waste post-harvest wheat and paddy residues. *Int. J. Recycling Org. Waste Agric*. **3**:127–132.

Costa-Silva, F., Marques, G., Matos, C.C., Barros, AIRNA, Nunes, F.M. 2011. Selenium contents of Portuguese commercial and wild edible mushrooms. *Food Chem.* **126**:91–96.

Cremades, O., Diaz-Herrero M.M.D., Aguilar, P.C., Gutierrez-Gil, J.F., Fontiveros, E., Morgado, B.R., Parrado, J., Bautista, J. 2012. Preparation and characterisation of selenium-enriched mushroom aqueous enzymatic extracts (MAEE) obtained from the white button mushroom (*Agaricus bisporus*). *Food Chem*. **133**:1538–154.

Da Silva, M.C.S. Naozuka, J., Luz, J.M.R.D., Assuncao, L.S.De, Oliveira, P.V., Vanetti, M.C.D., Bazzolli, M.S., Kssuya, M.C.M. 2012. Enrichment of *Pleurotus ostreatus* mushrooms with selenium in coffee husks. *Food Chem*. **131**:558–563.

Dernovics, M., Stefánka, Z., Fodor, P. 2002. Improving selenium extraction by sequential enzymatic processes for se-speciation of selenium-enriched *Agaricus bisporus*. *Anal Bioanal Chem.* **372**:473–480.

Falandysz, J. 2008. Selenium in edible mushrooms. *J. Environ. Sci.* **26**:256–299.

Gergely, V., Kubachka, K.M., Mounicou, S., Fodor, P., Caruso, J.A. 2006. Selenium speciation in *Agaricus bisporus* and *Lentinula edodes* mushroom proteins using multi-dimensional chromatography coupled to inductively

coupled plasma mass spectrometry. *J. Chromatogrphy A.* **1101**:94–102.

Hossain, S., Hashimoto, M., Choudhury, E.K., Alam, N., Hussain, S., Hasan, M., Choudhury, S.K. and Mahmuds, I. 2003. Dietary mushroom (*Pleurotus ostreatus*) ameliorates atherogenic lipid in hypercholesterolaemic rats. *Clin. Exp. Pharmacol. Physiol.* **30**:470–475.

Jayakumar, T., Thomas, P.A., Geraldine, P. 2007. Protective effect of an extract of the oyster mushroom, *Pleurotus ostreatus*, on antioxidants of major organs of aged rats. *Exp. Gerontol.* **42**:183–191.

Johns, T. and Eyzaguirre, P.B. 2007. Biofortification, biodiversity and diet: A search or complementary applications against poverty and malnutrition. *Food Policy* **32**:1–24.

Jope, R.S. 2003. Lithium and GSK-3 one inhibitor, two inhibitory actions, multiple outcomes. *Trends in Pharmacol. Sci.* **24**:441–443.

Kora, A.J. 2018 a. *Bacillus cereus*, selenite-reducing bacterium from contaminated lake of an industrial area: a renewable nanofactory for the synthesis of selenium nanoparticles. *Biores. Bioprocess.* **5**:1. https://doi.org/10.1186/s40643-018-0217-5

Kora, A.J. 2018 (b). Tree gum stabilised selenium nanoparticles: characterization and antioxidant activity. *IET Nanobiotechnol.* **12**:658–662

Kora, A.J. 2020. Nutritional and antioxidant significance of selenium-enriched mushrooms. *Kora Bulletin of the Nat. Res. Centre*. **44**:1-9.

Kora, A.J., Rastogi, L. 2017. Bacteriogenic synthesis of selenium nanoparticles by *Escherichia coli* ATCC 35218 and its structural characterisation. *IET Nanobiotechnol.* **11**:179–184. https://doi.org/10.1049/iet-nbt.2016.0011

Malinowska, E., Krzyczkowski, W., Herold, F., Lapienis, G., Slusarczyk, J., Suchocki, P., Kuras, M., Turlo, J. 2009. Biosynthesis of selenium-containing polysaccharides with antioxidant activity in liquid culture of *Hericium erinaceum*. *Enzym Microb Technol* **44**:334–343.

Marshall, T.M. 2015. Lithium as a nutrient. *J. Am. Phys. Surg.* **20**:104–109.

Mcclung, C.A. 2007. RolE for the clock gene in bipolar disorder. *Cold Spring Harbor Symposia on Quantitative Biology.* **72**:1–8.

Milovanovic, I., Lajin, B., Braeuer, S., Steiner, O., Lisa, F., Goessler, W. 2019. Simultaneous selenium and sulfur speciation analysis in cultivated *Pleurotus pulmonarius* mushroom. *Food Chem.* **279**:231–236.

Munoz, A.H.S., Kubachka, K., Wrobel, K., Corona, J.F.G., Yathavakilla, S.K.V. 2006. Caruso JA and Wrobel K. Se-Enriched mycelia of Pleurotus ostreatus distribution of selenium in cell walls and cell membranes/cytosol. *J. Agricult. Food Chem.* **54**:3440–3444.

Olga, T., Alla, P. 2017. Selenium compounds biotransformed by mushrooms: not only dietary sources, but also toxicity mediators. *Curr. Nutr. Food Sci.* **13**:82–96.

Oliveira, A.P., Naozuka, J. 2019. Preliminary results on the feasibility of producing selenium-enriched pink (*Pleurotus djamor*) and white (*Pleurotus ostreatus*) oyster mushrooms: bioaccumulation, bioaccessibility, and se-proteins distribution. *Microchem. J.* **145**:1143–1150.

Prange, A., Sari, M., von Ameln, S., Hajdu, C., Hambitzer, R., Ellinger, S., Hormes, J. 2019. Characterization of selenium speciation in selenium-enriched button mushrooms (*Agaricus bisporus*) and selenized yeasts (dietary supplement) using X-ray absorption near-edge structure (XANES) spectroscopy. *J. Trace Elem. Med. Biol.* **51**:164–168.

Rabinovich, M., Figlas, D., Delmastro, S., Curvetto, N. 2007. Copper-and zinc enriched mycelium of *Agaricus blazei Murril*: Bioaccumulation and bioavailability. *J. Med. Food* **10**:175–183.

Rathore, H., Sharma, A., Prasad, S., Sharma, S. 2018. Selenium bioaccumulation and associated nutraceutical properties in *Calocybe indica* mushroom cultivated on se-enriched wheat straw. *J Biosc. Bioeng*. **126**:482–487.

Rodriguez Estrada, A.E., Lee, H-J., Beelman, R.B., MdM, J.G., Royse, D.J. 2009. Enhancement of the antioxidants ergothioneine and selenium in *Pleurotus eryngii* var. eryngii basidiomata through cultural practices. *World J. Microbiol. Biotechnol.* **25**:1597–1607.

Savic, M., Anedjelkovic, I., Duvnjak, D., Matijasevic, D., Avramovic, A.., Niksic, M. 2012. The fungistatic activity of organic selenium and its application to the production of cultivated mushrooms *Agaricus bisporus* and *Pleurotus* spp. *Arch. Biol. Sci.* **64**:1455–1463.

Savic, M., Petrovic, J., Klaus, A., Niksic, M., Rajkovic, M., Filipovic, N. 2009. Antic-Mladenovic S. Growth and fruit body formation of *Pleurotus ostreatus* on media supplemented with inorganic selenium. *Zbornik Matice Srpske Za Prirodne Nauke*. **1**:209–215.

Schrauzer, G.N. 2002. Lithium: occurrence, dietary intakes, nutritional essentiality. *J. The Amer. College Nutr.* **21**:14–21.

Sharma, S., Goyal, R., Sadana, U.S. 2014. Selenium accumulation and antioxidant status of rice plants grown on geleniferous soil from northwestern India. *Rice Sci.* **21**:327–334.

Silva, M.C.S., Naozuka, J., da Luz, J.M.R.., Assunção, L.S., Oliveira, P.V., Vanetti, M.C.D., Bazzolli, D.M.S. and Kasuya, M.C.M. 2012. Enrichment of *Pleurotus ostreatus* mushrooms with selenium in coffee husks. *Food Chem.* **131**:558–563.

Stefánka, Z., Ipolyi, I., Dernovics, M., Fodor, P. 2001. Comparison of sample preparation methods based on proteolytic enzymatic processes for sespeciation of edible mushroom (*Agaricus bisporus*) samples. *Talanta*. **55**:437–447.

Vetter, J. 2005. Lithium content of some common edible wild-growing mushrooms. *Food Chem.* **90**:31–37.

Witkowska, A. 2014. Selenium-fortified mushrooms-candidates for nutraceuticals? *Austin Therapeutics,* **1**:4.

Zaidman, B.Z., Yassin, M., Mahajna, J. and Wasser, S.P. 2005. Medicinal mushroom modulators of molecular targets as cancer therapeutics. *Appl. Microbiol. Biotechnol.* **67**:453–468.

Zhao, L., Zhao, G., Du, M., Zhao, Z., Xiao, L., Hu, X. 2008. Effect of selenium on increasing free radical scavenging activities of polysaccharide extracts from a se-enriched mushroom species of the genus *Ganoderma*. *Eur. Food Res. Technol.* **226**:499–505.

Zhao, L., Zhao, G., Zhao, Z., Chen, P., Tong, J., Hu, X. 2004. Selenium distribution in a se-enriched mushroom species of the genus *Ganoderma*. *J Agric. Food Chem.* **52**:3954–3959.