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Review Article

Black Truffle-An Exorbitant Creation of Nature

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Abstract

Truffle, an edible fungus belonging to the phylum- Ascomycota, is an exotic cuisine delicacy. Among these, black truffles are highly appreciated because of the presence of their excellent aroma. This characteristic aroma of black truffles is due to volatile organic compounds, like alcohols, ketones, aldehyde and sulphur, which are secreted by their fruiting bodies. In addition to imparting aromas, these nutritionally important, cuisine delicacies also display bioactive properties beneficial for human health. The bioactive properties exhibited by different species of black truffles include antiviral, antibacterial, anti-mutagenic, anti-fatigue, anti-diabetic, antinephritic, antiproliferative, antiangiogenetic, anti-inflammatory, antioxidant and hepato-protective properties. This review provides a description of black truffles, the different chemical compounds imparting their excellent aroma and the different bioactive properties depicted by their different species.

Keywords: Truffle; Ascomycota; Aroma; Bioactive Properties

Introduction

Truffle, an edible fungus of subterranean origin had attained the status of exotic delicacy from classical times. By the dawn of the 15th century, citizens of France crowned Périgord truffle (*Tuber melanosporum*) as the most exorbitant fungus ruling the French cuisine. Although, they are present round the country but regions of *Périgord* and *Provence–Alpes-Côte d'Azur* are the main *truffières* (truffle grounds) of France. Apart from *Tuber melanosporum* (black winter truffle), there are ~185 more species of Tuber. *T. brumale* (Muscat black truffle); *T. aestivum* (Scorzone black truffle); *T. indicum* (Chinese black truffle); *T. himalayanse* (Himalayan black truffle) are few more expensive culinary truffles popular among the natives of the dwelling region. In addition to "True truffles", club fungi belonging to the phylum Basidiomycetes introduces the category of "False truffles". Native truffles (true truffles) belong to the phylum- Ascomycota, kingdom- Fungi, genus- Tuber, order- Pezizales. Presence of spores inside the structure inimitably distinguishes Ascomycetes from that of Basidiomycetes, for their intrinsic nature of bearing the spores in the outer region.

Drawbacks of planned farming till date do not permit direct cultivation of truffles. As a result, despite of having enormous consumer demand, the gathered produce is incapable to meet the need of the market. For production, generally acorns are planted in calcareous region and soil from *truffières* is uniformly spread, maintaining other environmental parameters. If the process responds in a positive manner, then truffles get produced after 3 years but maximum peak of production may take 5-25 years later the initial period. The process of production is extremely time consuming, therefore the farming business is not profitable if considered from a commercial point of view. But to increase the production, initiatives for foresting the barren areas had been undertaken by government authorities, as truffle production increases in planted regions, particularly oak trees. Truffles are mostly grown under the ground at ample depths. Upon maturity, they crack the ambience of the surroundings by emitting volatiles and get detected by the fragrance with the aid of trained dogs and female pigs. It is necessary to increase the global yield of such immensely beneficial truffles, in order to decrease their cost so that a greater section of the population can acquire the benefit. To avail this purpose, approaches, like undertaking their inoculation and carrying out fermentation procedures may be advantageous [1].

Truffles: Aromatic Bouquet of Nature

Truffles especially black truffles are hugely treasured due to their characteristic aroma [2]. It is well known that olfactory discernment is stimulated by the volatile organic compounds which are secreted by fruiting bodies [3]. Volatile organics, released by these truffles, are thoroughly analysed and identified for their directory flavours. Most frequently detected volatiles are alcohols, ketones, aldehyde and sulphur. Truffles, at various phases of life cycle, release volatiles to interact with surrounding organisms and plants [4]. Sensory analyses have led to the findings that aroma impression of the truffles has been principally given by sulphides and aldehydes compounds. Presence of alcohols, ketones and short chain fatty acids also contribute to different descriptive flavors. From the description of the aroma flavors, it has been predicted that the black truffles tend to emit higher amount of aromatics as compared to summer truffles [2]. In black truffles, the most detected volatiles belong to alcohol group which produce a characteristic odour of phenols while in case of summer truffles, beta phenylethanol is the most emitted compound which leads to an aroma typical of roses. The role of different chemical constituents and their contributing flavour is depicted in the Figure 1.

Bioactive Potential of Truffles: Case Studies

Apart from the bouquet of aromas and nutritional importance, scientists unravelled the role of bioactives present within the truffles in up regulating the health status of human system. Bioactivities of truffles cover antibacterial, antiviral, anti-mutagenic, anti-inflammatory as well as antioxidant and hepato-protective properties. The mechanism of their protective action is illustrated in the following sub-sections based on model species study.

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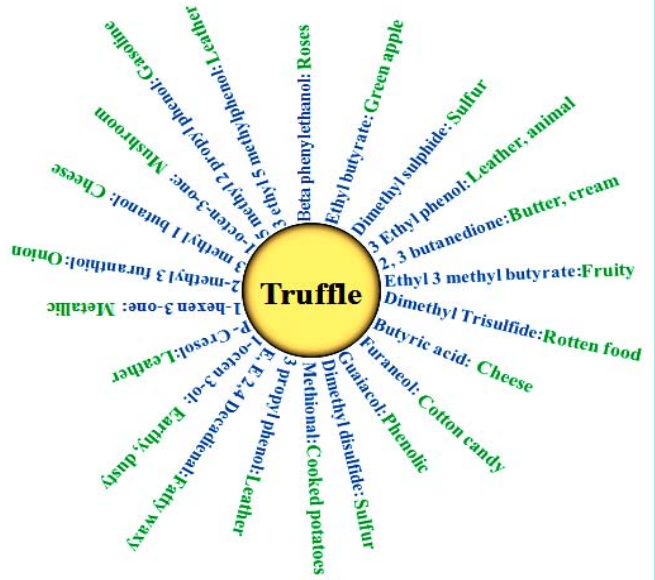

Figure 1: Diagrammatic representation of chemical components and their respective aroma present in truffles.

Anti-fatigue activities of tuber melanosporum

Jiang et al. [5] studied the anti-fatigue effects of *T. melanosporum* on BALB/c mouse. Evaluation of the model was performed by measuring the endurance of the mouse during swimming and running ability tests. Treatment of mice with different concentration of *T. melanosporum* for 14 days demonstrated increment of hepatic and muscular ATP, validated by 30 min swimming in comparison to control. Reducing levels of serum lactic dehydrogenase and lactic acid further corroborated with the initial data. During the study, effect of *T. melanosporum* on hormonal levels was also carried on both male and female mice. Levels of serum progesterone, testosterone and estradiol although increased in both male and female but serum luteinizing hormone significantly decreased in female mice. In addition, follicle stimulating hormone increased in males whereas reducing behaviour was observed in females. Another aspect of the scenario revealed, increasing levels of glutathione peroxidise and superoxide dismutase and reducing levels of malondialdehyde and reactive oxygen species. From the study, it can be suggested that the anti-fatigiue activities of *T. melanosporum* involves complex regulation of energy and hormone metabolism and controlling levels of oxidative stress.

Antidiabetic and antinephritic activities of tuber melanosporum

Jiang et al. [6] investigated about the anti-diabetic and anti-nephritic properties of *T. melanosporum* on db/db mice. A prolong study of eight weeks using varied oral dosage of *T. melanosporum* (0.2g-0.4 g/kg) in addition to metformin (0.1 g/kg) significantly reduced concentrations of triglyceride, cholesterol, plasma glucose, body weight, glycated haemoglobin whereas increased concentration of high density lipo-protein cholesterol were observed in serum of mice, depicting the hypolipidemic and hypoglycaemic effects. The mechanism of anti-glycemic effect is attained by promoting glucose *via* increasing levels of hepatic glycogen and pyruvate kinase. Apart from this, various factors are also regulated by *T. melanosporum*, as it enhances expression of manganese superoxide dismutase 2, nuclear respiratory factor 2 (Nrf2), heme oxygenase 1 and 2, catalase and reduces expression of phosphor-nuclear factor-κB, phosphor-janus kinase 2, phosphor-signal activator and transducer of transcription 3 and protein kinase C alpha in kidneys. Upon detail critical analysis of the study, it can be understood and possible to suggest that *T. melanosporum* shows its anti-diabetic and anti-nephritic activities by improvising Nrf2 signaling pathway via modulation of oxidative stress and cytokines.

Antioxidant and cytotoxic activities of tuber aestivum

The antioxidant as well as cytotoxic activities of *Tuber aestivum*, a black truffle, has been studied by Beara et al. [7]. The antioxidant capacity of *T. aestivum* was determined by the FRAP assay, scavenging effect on DPPH radical and hindrance of lipid peroxidation. Antioxidant potential of *T. aestivum* has also been determined by Villares et al. [8]. Thus, such studies reveal the application of this black truffle in reducing oxidative damage and imparting protection to the human system.

The toxicity potential of *T. aestivum* towards living cells was investigated by determining the effect of methanol and water extracts of this black truffle on both tumour and non-tumour human cell lines [7]. Inhibition of growth of cells was observed in breast adenocarcinoma cell line and cervix carcinoma cell line, when treated with extracts obtained from *T. aestivum*. This cytotoxic effect resulting in inhibition of cell growth may be attributed to the presence of phenolics, like p-hydroxybenzoic acid, catechin, epicatechin etc. Polysaccharides obtained from broth of both batch and fed-batch fermentation system of *T. aestivum* has been reported to display inhibition towards the growth of tumors [9].

Antiproliferative, antiangiogenetic, antioxidant and antimicrobial activities of terfezia claveryi

Dahham et al., [10] reported their studies on the antiproliferative, antiangiogenetic and antioxidant properties of the black truffle, *Terfezia claveryi*. The cytotoxicity of *T. claveryi* extracts on the 4 cell lines of cancer (PC3, HT29, U-87MG and MCF-7) was estimated by an assay of MTT cytotoxicity and the anti-angiogenic efficiency was also tested. Activities depicted by the truffle extracts were against the cancer cell lines, determining their anticancer behaviour. Upon testing solvent extracts obtained from *T. claveryi* for antioxidant properties, ethanol extract of this black truffle displayed potential antioxidant activity. They attributed such important bioactive properties of *T. claveryi* to the presence of compounds like fatty acids, phytosterol, triterpenes and vitamins in the truffle extracts. Thus, owing to such important properties, this black truffle may find applications in medicinal industries and in the health sector. The antibacterial and antiviral activities of *Terfezia claveryi* are reported by El Enshasy et al., [11]. Studies also showed the inhibition of bacterial species like *Staphylococcus aureus* [12] and *Pseudomonas aeruginosa* by aqueous extractions obtained from *Terfezia claveryi* [13]. Such antimicrobial activity of Terfezia was attributed to the production of peptide antibiotics by the species [12]. Additionally, extractions obtained from the truffle Terfezia also displayed antiviral activities [10].

Antimicrobial and antioxidant action of terfezia boudieri

The antimicrobial action of *Terfezia boudieri*, a black truffle belonging to deserts and found in Southern Tunisia have been reported

by Hamza et al., [15]. Methanolic extracts obtained from this truffle exhibited remarkable antibacterial activity against the 7 bacterial species, of which, *Escherichia coli, Salmonella typhimurium* and *Pseudomonas aeruginosa*, are gram negative and the bacterial speies, *Bacillus subtilis, Enterococcus faecalis, Staphlyococcus aureus,* and *Staphlyococcus* epidermis which are gram positive. Hussain and Al-Ruqaie [14] have reported the extractions of *Terfezia* using methanol to exhibit action against both gram (+ve) and gram (-ve) bacterial species. Dogan and Aydın [16] also reported action of *T. boudieri* against gram (+ve), gram (-ve) bacteria and also the pathogenic yeast *Candida albicans*. This property has been attributed to extractions of *T. boudieri*, which have been found to contain phenolic compounds like catechin, cinnamic acid, ferulic acid, p-coumaric acid. This desert black truffle, *T. boudieri*, has been reported to exhibit antioxidant activities by Hamza et al. [15] and Hussain and Al-Ruqaie [14]. Dogan and Aydın [16] also reported *T. boudieri* to possess a high antioxidant capacity by studying its DPPH radical scavenging effects.

Conclusion

From the aforementioned studies, it is apparent to decipher that "True Truffles" hold a very high position in culinary industry not only for its aroma but also for its immense significant effect on human system. As the chemical compound determines the flavour, therefore artificial intelligence system in association with biosensors can be used to determine the chemical components present in respect to the flavour of the truffle, which keeps a due for the scientists to work on. In addition, based on the compounds present, it will be easy to hypothesize and determine the effect of the bioactive compounds present in the truffle on human system.

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