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The Precious Truffles: Bioactive Compounds as a Source of Various Biological Activities

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Abstract
Truffles, esteemed members of the kingdom Fungi, are categorized under the phylum Ascomycota and the class Ascomycetes. They belong to the order Pezizales and the family Tuberaceae, with their most prominent and celebrated genus being *Tuber*. Truffles provide numerous health benefits due to their bioactive compounds. They have antioxidant, anticancer, antiviral, antimicrobial, liver-protective, anti-mutagenic, and anti-inflammatory properties. Truffles are abundant in bioactive compounds, including ascorbic acid, ergosterol, phenolics, flavonoids, terpenoids, phytosterols, and polysaccharides etc. This review primarily focuses on exploring the nutritional composition, secondary metabolites, and biological activities of *Tuber melanosporum* Vittad, *Tuber magnatum* Pico, *Tuber borchii* Vittad, *Tuber gennadii*, *Tuber aestivum* Vittad, *Tirmania pinoyi*, and *Tirmania nivea*.

Keywords: Biological activities; Medicinal mushrooms; Secondary metabolites; Truffles

Introduction
Fungi in general and mushrooms especially are supposed to have huge medicinal potential and yet remain under investigated with regard to such properties. Many fungi have demonstrated attributes such as anticancer activity and immune system stimulation (Elkhateeb et al., 2018; Elkhateeb et al., 2019 a,b,c; Elkhateeb et al., 2020 a,b,c; Elkhateeb, 2020; Daba et al., 2020; Elkhateeb and Daba 2020 a,b; Elkhateeb et al., 2021 a,b,c; Elkhateeb and Daba, 2021 a,b,c,d,e,f; ALKolaibe et al., 2021; Elkhateeb et al., 2022 a,b; Hapuarachchi et al., 2018; Elkhateeb et al., 2023 a,b,c,d; Soliman et al., 2022; Elkhateeb et al., 2024). Edible fungi are divided into two categories such as epigeous carpophores, known as mushrooms, and hypogeous varieties that develop underground called truffles (Thomas et al., 2020; 2021 a,b). Truffles, which grow in a symbiotic relationship with plant roots are recognized worldwide as one of the most luxurious foods due to their scarcity, distinctive fragrance, and significant nutritional benefits. These benefits include antioxidant, anti-inflammatory, antiviral, antimicrobial, hepatoprotective, anti-mutagenic, antitubercular, immunomodulatory, antitumor, and aphrodisiac properties (Lee et al., 2020). The distinct flavor and aroma of truffles are primary drivers behind their widespread allure as a culinary delicacy (Mustafa et al., 2020). The term "truffles" likely originates from the Latin word "tubera," the plural form of "tuber," denoting a lump, hump, or swelling. The Latin called this fungus "tuber," derived from "tumere," indicating its spherical shape (Patel, 2012). Although the Tuber genus encompasses over 200 species, many of them remain unidentified, mainly due to their inconspicuous, small-sized fruiting bodies lacking culinary significance (Payen et al., 2014). Truffles live in symbiosis with plant roots, generally forming ectomycorrhizas. Ectomycorrhizae positively impact plant growth in nature (Splivallo, 2008). Truffles are a category of fungi that have been

primarily used in gourmet cuisine but have lately also been researched for their various properties and applications. Truffles stand out as one of the rarest and most esteemed varieties of edible fungi, renowned for their unique aroma and rich nutritional profile. Yet, their chemical composition is largely influenced by the specific characteristics of their growth environment. In recent times, several studies have delved into the phytoconstituent content of various truffle species (Segneanu et al., 2021).

Volatile compounds emitted by truffles serve as olfactory signals for mammals and insects, aiding in the location of these prized fungi underground and facilitating spore dispersion. Additionally, these compounds diffuse freely in the soil, influencing interactions with microorganisms and plant roots, potentially orchestrating a multifaceted molecular dialogue among soil fauna and flora (Splivallo et al., 2011). The distinct flavor of truffles stands out as a primary factor driving their global appeal as a sought-after food item. The steep price of truffles stems from the challenging and labor-intensive process of their treasure hunting. In their natural habitat, truffles entice mammals such as wild pigs or boars and squirrels, which consume the fruiting bodies and aid in spore dispersal (Mustafa et al., 2020). Truffle hunters have historically employed pigs and, more recently, trained dogs to locate these underground treasures (Splivallo et al., 2011). Truffles belong to the kingdom Fungi, phylum Ascomycota, class Ascomycetes, order Pezizales, family Tuberaceae, and the most common genus *Tuber.* Truffles are in association with lots of tree species such as oak, hazelnut, linden, beech, poplar, chestnut, walnut and pine (Üstün et al., 2018). Today, the most popular species of truffles are *Tuber magnatum*, *T. melanosporum* and *T. aestivum.*

The genus Tuber holds significant economic importance within the realm of truffles, encompassing esteemed species such as *Tuber magnatum* Pico (White truffle), Tuber melanosporum Vittad. (Black truffle), and *Tuber aestivum* Vittad. (Summer truffle), renowned for their characteristic aroma (Costa et al., 2015). These species are traditionally harvested in many countries in Europe, like Italy, France, and Spain. *Tuber indicum* Cooke & Massee is exclusively harvested in Asia, as noted by Reyna & Garcia-Barreda (2014). Other genera, including *Terfezia* or *Tirmania*, also hold culinary appeal, albeit their sensory attributes are less esteemed globally. These genera, often referred to as desert truffles, primarily thrive in the arid and semi-arid regions of the Mediterranean basin, as highlighted by Zambonelli et al. (2014).

Truffle Aroma: Black and White Varieties: Truffles exhibit variations in texture—ranging from wrinkled and bruised to smooth and reticulate and color, spanning white, brown, and black hues. The white truffle category encompasses species such as *Tuber magnatum*, *T. maculatum*, *T. borchii*, *T. dryophilum*, *T. puberulum, T. oregonense* (Oregon white truffle*), T. excavatum*, and *T. latisporum*. On the other hand, black truffles include *T. melanosporum* (Perigord truffle), *T. aestivum* (summer truffle), *T. brumale, T. uncinatum* (Burgundy truffle), *T. indicum*, and *T. himalayense* (Zhang et al., 2005). Approximately 30 truffle species are commercially traded, valued for their scarcity and distinctive aroma, rendering them among the world's most expensive foods (Vahdatzadeh and Splivallo, 2018). Numerous aspects of truffle cultivation and utilization warrant further investigation. More research is required to determine the best ways to use the understanding of truffle scent components to value-added truffle or truffle-related goods.

The quality of truffles can vary greatly among different species (Mustafa et al., 2020). Nonetheless, certain species are highly prized and sought after across various countries. Europe is home to the most esteemed truffles, including *Tuber melanosporum* Vittad. (Périgord black truffle), *Tuber magnatum* Pico (Italian white truffle), *Tuber aestivum* Vittad. (Summer or Burgundy truffle), and *Tuber borchii* Vittad. (Bianchetto truffle) (Mustafa et al., 2020).

Nutritional profile of truffles

Investigation of nutritional profile of most truffles showed that fresh truffles fruiting bodies, are a rich source of carbohydrates and proteins (Kalaˇc, 2013). Truffles were found to contain a few trace amounts of minerals, amino acids, and fatty acids (Lee et al., 2020). However, other minor chemical constituents, such as phenolic compounds and tocopherols, have only been studied in *T. aestivum* and *T. magnatum* truffles (Beara et al., 2014). Some of these compounds are known for their biological activities, including free radical scavenging, metal chelation, and inhibition of lipid oxidation in response to reactive oxygen species (ROS) (Sánchez, 2017). Truffles have been reported to be rich in proteins, essential amino acids, fatty acids, ash, carbohydrates, dietary fiber, minerals, and vitamin D. Additionally, they possess distinct aromas—earthy, musky, and pungent—stemming from their volatile organic compounds, which include alcohols, aldehydes, alkanes, esters, ketones, terpenes, and more.

Truffles also have bioactivities that are anti-inflammatory, hepatoprotective, antiviral, antibacterial, and antioxidant (Üstün et al., 2018). Moreover, studies have explored the bioactivities of desert truffles from the *Terfezia* and *Tirmania* species, revealing antiviral, antimicrobial, antimutagenic, antioxidant, and anti-inflammatory properties (Dahham et al., 2018). It has been previously reported that truffles are rich in proteins, fats, fatty acids, dietary fiber, ash, essential amino acids (such as methionine, phenylalanine, valine, serine, isoleucine, and threonine), carbohydrates, vitamin D, and metals (including potassium, phosphorus, iron, copper, zinc, and manganese) (Üstün et al., 2018). Gioacchini et al. (2005), identified 36 volatile organic compounds (VOCs)—including alkanes, alcohols, esters, aldehydes, ketones, and terpenes—distributed across six different species of white and black truffles: *Tuber magnatum*, *T. borchii*, *T. dryophilum*, *T. aestivum*, *T. mesentericum*, and *T. brumale*.

Truffle bioactivities

Truffles, edible fungi from the phylum Ascomycota, are considered an exotic culinary delicacy. Black and white truffles, in particular, are highly prized for their exceptional aroma. This distinctive fragrance is attributed to volatile organic compounds such as alcohols, ketones, aldehydes, and sulfur compounds secreted by their fruiting bodies. Besides their aromatic qualities, these nutritionally valuable delicacies also exhibit bioactive properties that benefit human health (Das et al., 2020). Bioactive substances like ascorbic acid, ergosterol, phenolics, flavonoids, terpenoids, phytosterol, and polysaccharides abound in truffles. Particularly, edible mushrooms are unable to synthesise flavonoids, which are valued as an important secondary metabolite of natural products because of their diverse biological properties, including antioxidative, anti-inflammatory, anti-mutagenic, and anticancer properties. In contrast, truffles contain an abundance of these valuable metabolites (Panche, et al., 2016; Gil-Ramírez et al., 2016).

Biological activities of Black truffle

Black truffle, esteemed both in culinary and medicinal contexts, is highly valued worldwide for its nutritional and therapeutic significance. It is particularly known for its potent antihyperlipidemic and anti-inflammatory effects. These findings contribute to the growing understanding of the therapeutic benefits of black truffles. Black truffles hold promise as a potential food supplement and a natural source of pharmaceutical agents for diabetes prevention and treatment (Wu et al., 2022). *Tuber melanosporum*, or black truffle, is a highly prized underground edible fungus, enjoyed globally for its delectable flavor (Wu et al., 2022). Their widespread acclaim is largely due to their remarkable nutritional and medicinal qualities (Napoli et al., 2010).

Black truffles are packed with carbohydrates, proteins, amino acids, fatty acids, vitamins, minerals, phenolics, and flavonoids, providing a diverse and nutritious composition (Wu et al., 2022). Furthermore, past investigations have underscored the manifold therapeutic potential of black truffles, including their antioxidative, anti-inflammatory, immunosuppressive, antimutagenic, anticarcinogenic, and antimicrobial properties, all of which contribute to human health benefits (Dahham et al., 2018).

Black truffle, a staple in traditional folk medicine, has been historically employed as an adjunctive treatment for various ailments, including eye disorders and gastric cancer. Nonetheless, limited research has delved into its potential for alleviating hyperlipidemia and inflammation in diabetic contexts (Yan et al., 2017; Jiang et al., 2018).

***Biological activities of* White truffles**

White truffles, such as *Tuber magnatum* and *Tuber borchii*, are ectomycorrhizal species known for their edible ascocarps. These varieties are highly renowned and fetch premium prices, primarily harvested from natural habitats in European countries. However, the annual production of *Tuber magnatum* often falls short of meeting the high demand, sparking significant interest in its cultivation as a research focus (Bach et al., 2021). *Tuber magnatum*, along with other species like Tuber borchii, Tuber dryophilum, and Tuber puberulum, is characterized by smooth, pale-colored ascocarps. In contrast, the majority of other edible truffles, such as *T. melanosporum*, *T. aestivum*, and *Tuber macrosporum*, are referred to as "black truffles" due to their brown, black, and warty surfaces. While the ascocarps of *T. magnatum* are generally smaller than those of European black truffles like *T. melanosporum* and *T. aestivum*, they are somewhat larger than those of other white truffle species like *T. borchii* and *T. maculatum*. Like all truffles, *Tuber magnatum* harbors its spores within its hypogeous ascocarps. Due to this characteristic, truffles are unable to actively release their spores and rely less on wind dispersal compared to many other members of the Pezizaceae family (Graziosi et al., 2022). White truffles have antioxidant, antiviral, antimicrobial, hepatoprotective, anti-mutagenic, and anti-inflammatory bioactivities. It is stated in the recent researches that the bioactive compounds existed in truffles could be used as potential therapeutic agents (Üstün et al., 2018). This review encompasses general insights into the nutritional composition, aromatic characteristics, biological functions, and culinary applications of various truffles. Truffles are rich in therapeutic compounds with anti-inflammatory, antioxidant, antiviral, antimicrobial, anti-mutagenic, anti-carcinogenic and hepatoprotective bioactivities. Truffles are an important source of natural bioactive compounds that could be used as potential therapeutic agents (Wang & Marcone, 2011). The different proportion of total metabolites identified in different truffles species can be considered as evidence of the influence exerted by genetic and environmental conditions (Segneanu et al., 2021). These bioactive substances, which include phenolics, polysaccharides, terpenoids, fatty acids, and organic acids, have been shown to have antidiabetic, anti-inflammatory, antibacterial, antioxidant, and hepatoprotective properties.

The relationship between different bioactivities (antioxidant, antimicrobial and anti-proliferative activities) directly with one or a group of specific bioactive molecules it's difficult (Patel et al., 2017). Truffle methanolic extracts exhibited significant antibacterial activity against various bacterial strains. Notably, this included gram-negative species such as *Escherichia coli*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa*, as well as gram-positive bacteria like *Bacillus subtilis*, *Enterococcus faecalis*, *Staphylococcus aureus*, and *Staphylococcus epidermis* (Hamza et al., 2016 a). Black truffles from various species demonstrate an array of bioactive properties, including antiviral, antibacterial, antimutagenic, anti-fatigue, antidiabetic, antinephritic, antiproliferative, antiangiogenic, anti-inflammatory, antioxidant, and hepatoprotective effects (Das et al., 2020).

Famous truffles and their biological activities

Tejedor-Calvo et al., (2021), chemically characterized ten truffle species belonging to the *Tuber* and *Terfezia* genera. Their study evaluated the proximate composition, individual nutrient compounds, and certain bioactive molecules of these truffles. These species were also assessed for their bioactive properties, including antioxidant, antimicrobial, and cytotoxic potentials. Carbohydrates emerged as the primary macronutrients in these truffles, with proteins following closely. Additionally, the levels of polyunsaturated fatty acids were generally higher in truffles, except for *Tuber magnatum* and *Terfezia arenaria*, which exhibited a more saturated fatty acid profile. In comparison among the species, Tuber magnatum exhibited the highest levels of total phenolic compounds and yielded the best results across the four methods utilized to assess antioxidant activity, as reported by Tejedor-Calvo et al. (2021). Conversely, only extracts from five studied truffle species (*Terfezia magnusii, Tuber aestivum, Tuber gennadii,* and *Tuber melanosporum*) demonstrated a slight inhibition of microbial growth when tested against various bacteria. *Terfezia* and *Tuber* gennadii extracts exhibited potential in inhibiting the cellular growth of NCI-H460, HeLa, HepG2, and MCF-7 cell lines, indicating anti-proliferative activity. However, *T. arenaria* demonstrated some potential hepatotoxicity by inhibiting the growth of PLP2 cells, as noted by Tejedor-Calvo et al. (2021). Fratianni et al. (2007), reported on the antimutagenic activities of fresh and irradiated black truffles (Tuber aestivum) from Italy. The fresh truffle displayed a stronger inhibitory effect compared to the irradiated truffle. Furthermore, 52 polysaccharides were isolated from the fermentation systems of *Tuber melanosporum, Tuber indicum*, *Tuber sinense*, and *Tuber aestivum*, as well as from the fruiting bodies of *Tuber indicum*, *Tuber himalayense*, and *Tuber sinense*, through elution with an activated carbon column. These fermentation-derived polysaccharides exhibited invitro antitumor activity against a multitude of cancer cell lines such as HepG2 (human hepatocellular carcinoma), A549 (human lung adenocarcinoma), HCT-116 (Human colon carcinoma), SK-BR3 (human breast cancer), and HL-60 (Human promyelocytic leukemia) cells (Zhao et al., 2014).

***Biological activities of Tuber melanosporum* Vittad. (Black truffle)**

Zhao et al. (2014), discovered that polysaccharides isolated from *T. melanosporum* and their fruiting bodies exhibited antitumor activities against A549, HCT-116, HepG2, HL-60, and SK-BR-3 cell lines. This antitumor effect is attributed to the presence of β-d-glucan, a bioactive molecule responsible for targeting and inhibiting the cancer cells (Zhao et al., 2014). Zhang et al. assessed the effects of an aqueous extract on streptozotocin-induced hyperglycemic rats. The rats treated with truffle extract showed reduced glucose levels, comparable to those treated with the standard antidiabetic drug, glibenclamide. Samuel O. Ede et al. (2016), conducted a hypoglycaemic screening study under in-vivo conditions by administering 1000 mg/kg of *Tuber melanosporum* extract to alloxan-treated mice. This treatment significantly decreased blood glucose levels in the mice (Zhang et al., 2005). Samuel O. Ede et al. (2016), conducted a study on the antioxidant properties of the ethanolic extract of *Tuber melanosporum* (Figure, 1). Their findings demonstrated significant antioxidant activity, which they quantified by determining the IC_{50} value. The IC_{50} value, which indicates the concentration of the extract required to inhibit 50% of the free radicals, was found to be 251.100 µg/ml. This value reflects the potency of the extract as an antioxidant, suggesting that *Tuber melanosporum* could be a valuable source of natural antioxidant compounds (Samuel O. Ede et al. 2016).

Biological activities of Tuber magnatum Pico (White truffle)
Beara et al. (2014), demonstrated that methanol extracts of *T. magnatum* exhibited significant in vitro cytotoxic effects against various cancer cell lines, including HeLa, MCF-7, and HT-29. Additionally, the water extract showed, pronounced activity specifically against the MCF-7 breast adenocarcinoma cell line. Beara et al. (2014), demonstrated that *T. magnatum* extract inhibited the products of the COX-1 and 12-LOX pathways, including 12(S)-hydroxy-(5Z,8E,10E)-heptadecatrienoic acid (12-HHT), thromboxane B2 (TXB2), and 12(S)-hydroxy-(5Z,8Z,10E,14Z)-eicosatetraenoic acid (12-HETE). These compounds are known to be overexpressed in various inflammatory diseases (Figure 1). They also studied the antioxidant properties of *T. magnatum* and found that its water extracts exhibited significant antioxidant potential against nitric oxide radicals, demonstrating greater potency than propyl gallate (Beara et al., 2014).

Figure 1. Medicinally important mushrooms. (A) *Tuber magnatum* (B) *Tuber melanosporum* (Photographs were taken by Dr. Paul Thomas. Location: Stirling, University).

Biological activities of Tuber borchii Vittad (White truffle)
Angelini et al. (2015), investigated the antibacterial activity of methanol (MeOH) extracts, from the truffle *Tuber borchii* against *Streptomyces* species using the broth microdilution method. Their findings revealed that the MeOH extracts exhibited a dose-dependent inhibitory effect on seedling height and root length, and demonstrated significant antibacterial activity against *Streptomyces* species (Figure 2). Additionally, the antioxidant activity of these methanolic extracts was evaluated using the DPPH assay. The results indicated that between 19.2 and 38.7 mg of the extract were required to reduce 50% of the DPPH coloration, showcasing the extract's antioxidant potential (Angelini et al., 2015).

Biological activities of Tuber gennadii (Chatin) Pat. (= Loculotuber gennadii) (White truffle)
Eva Tejedor-Calvo et al. (2019), conducted a study on extracts from *Tuber gennadii*, which demonstrated promising potential in inhibiting the cellular growth of various cancer cell lines, including NCI-H460, HeLa, HepG2, and MCF-7. The concentrations required to inhibit 50% of cell growth (GI50) ranged from 19 to 78 µg/mL for NCI-H460, 33 to 301 µg/mL for HeLa, 83 to 321 µg/mL for HepG2, and 102 to 321 µg/mL for MCF-7 (Figure, 2). These findings suggest significant anti-proliferative activity against these cancer cell lines. Furthermore, *Tuber gennadii* extracts exhibited a slight inhibition of microbial growth when tested against various bacteria. This dual functionality, both in inhibiting cancer cell proliferation and exhibiting antimicrobial properties, highlights the potential therapeutic value of *Tuber Gennady* extracts in combating cancer and microbial infections (Eva Tejedor-Calvo et al., 2019).

Tuber aestivum Vittad. (Summer White truffle) biological activities
Marathe et al. (2020), tested the anti-angiogenic and anti-inflammatory potential of the petroleum ether and ethanol extracts of the truffle *Tuber aestivum* using the CAM and lipoxygenase inhibitory assays, respectively. Analysis of the extract's mass spectra revealed the presence of diverse compounds, potentially responsible for their observed anti-angiogenic and anti-inflammatory activities. The combined effects of the compounds within the petroleum ether and ethanol extracts likely contribute to their biological activity, as depicted in Figure 2. This study could be considered

as a basis for promoting research area on the health effects of truffles and their use as a functional food (Marathe et al., 2020).

Figure 2. Medicinally important mushrooms (A) *Tuber aestivum* (B) *Tuber borchii* and (C) *Tuber gennadii* (Photographs were taken by Dr. Paul Thomas. Location: Stirling, University).

Biological activities of *Tirmania pinoyi* (Maire) Malençon and *Tirmania nivea* (Desf.) Trappe (Desert truffle)

Tirmania pinoyi and *Tirmania nivea* have promising anti-inflammatory, wound healing and antiviral activities studied by Elkhateeb et al. (2024), and these results encouraged further studies on them to be used as functional foods or as sources of bioactive compounds. Hamza et al. (2016 b) found that the desert truffle, *Tirmania nivea*, exhibited remarkable inhibitory activity against three species of gram-positive bacteria and four species of gram-negative bacteria, including *Salmonella typhimurium*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, *Staphylococcus aureus*, *Staphylococcus epidermis*, and *Bacillus subtilis*. Additionally, truffles contain secondary antioxidant metabolites such as phenolics, flavonoids, tocopherol, carotenoids, and phytosterols, as depicted in Figure 3. Phenolics can be employed as an effective antioxidant and free radical scavenger because of their reducing power as hydrogen- or electron-donating agents.

Figure 3. Medicinally important mushrooms (A) *Tirmania nivea* (B) *Tirmania pinoyi* (Photographs were taken by Dr. Waill A. Elkhateeb. Location: National Research Centre of Egypt).

Compared to *Tirmania pinoyi*, *Tirmania nivea* has a substantially higher total phenolic content and more potential for antioxidants (Al-Laith, 2010). Despite their reported ethnomycological and nutritional values, the chemical composition of *Tirmania nivea* and *Tirmania pinoyi* has been reported by few literatures. Aboutabl et al. (2022), conducted GC–MS and HPLC analyses to describe the metabolic profiles of hydromethanolic extracts from *Tirmania nivea* and *Tirmania pinoyi* truffles. Their analyses revealed the presence of 18 metabolites in the extracts of *Tirmania nivea* and 11 polyphenols in those of *Tirmania pinoyi*. Additionally, they assessed the anticonvulsant, sedative, and analgesic activities of these edible mushrooms for the first time. The results showed that *Tirmania pinoyi* had strong anticonvulsant and sedative activities than *Tirmania nivea*. In addition, *Tirmania nivea* exhibited both central and peripheral analgesic activities (Aboutabl et al., 2022). Soliman et al., (2022), studied and evaluated the in-vitro nematicidal activity of two truffles mushroom *Tirmania nivea,* and *Tirmania pinoyi* extracts against *Meloidogyne incognita* juveniles and eggs (Figure, 3). The extracts derived from these two truffle mushroom varieties exhibited notable efficacy in causing mortality among Meloidogyne incognita second stage juveniles, achieving mortality percentages ranging from 79.3% to 97%. Instead, the tested truffles mushroom *Tirmania nivea,* and *Tirmania pinoyi* extracts exhibited some nematostatic and nematicidal activity against *Meloidogyne incognita* eggs as compared with the control after 7 days (Soliman et al., 2022).

Conclusion

From the above-mentioned studies, it is seeming 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. It is essential to direct more research efforts toward exploring the potential of natural products extracted from truffles and their effectiveness in combating diverse diseases and pathogens through bioassays. Their special aromatic specialties and potential therapeutic activities may add value to truffle-related foods although therapeutic amounts have not been determined and accepted by the medical community. It's apparent that additional scientific research should emphasize the integration of identified biochemical and biological properties into enhancing truffles and related products.

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