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Review Article

Phallus Impudicus – Trick or Treat (Ment)?

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Abstract

Phallus impudicus L. (from the Phallaceae family, Phallales order) is one of the most intriguing and recognisable fungi in mycology, famous for its exceptionally rapid growth and the intense, unpleasant odour of its mature fruiting body. Phytochemical studies indicate that extracts from P. impudicus are rich in polysaccharides (mainly β-glucans). These substances are being studied for their potential to stimulate the immune system (activation of lymphocytes and macrophages). The active compounds in P. impudicus also exhibit antiviral, antibacterial, antioxidant, anti-inflammatory and immunostimulatory properties. The wound healing properties of mushrooms include different mechanisms such as immune epithelial cells stimulation, and cytokines and growth factors release. The therapeutic effect of an ointment containing polysaccharides isolated from P. impudicus and a hydrogel containing P. impudicus extract in the wound healing process has been demonstrated in a full-thickness skin wound model and a difficult-to-heal wound arising in the course of diabetes. In conclusion, Phallus impudicus seems to be a fungus that is both known and unknown, edible and inedible, intriguing and devilish. Nevertheless, it is very interesting and worthy of our greater attention.

Introduction

Phallus impudicus L. (from the Phallaceae family, Phallales order) is one of the most intriguing and recognisable fungi in mycology, famous for its exceptionally rapid growth and the intense, unpleasant odour of its mature fruiting body. The Latin species name - Phallus impudicus (shameless) - refers to its phallic shape and rapid emergence from its cover (egg). In Europe, it is considered the healthiest medicinal mushroom. In China it is known as “Wuqunsun”. In Poland it has a lot of names stinking hellebore, stinking hellebore, shy hellebore. In an old Polish word meaning a person who is disgraced or causes scandal [1-4]. The Phallus impudicus has earned its place in the Guinness Book of Records as the fastest growing mushroom in the world. It grows at a rate of 5 mm per minute - you can see it growing before your eyes. It reaches its final size in 1.5 to several hours. The species was formally described by Carl Linnaeus in 1753. The taxonomy is presented in Table 1.

Table 1: Taxonomy and nomenclature.

Category	Taxon
Domain	Eukaryotes
Kingdom	Fungi
Phylum	Basidiomycota
Class	Agaricomycetes
Order	Phallales
Family	Phallaceae
Genus	Phallus
Species	Phallus impudicus

Phallus impudicus is a rather peculiar and intriguing fungus. It looks exactly as its taxonomic name suggests - phallus, which is associated with the penis. Indeed, it is a fungus with an unusual structure. Initially, the fruiting body (white or cream-coloured) is egg-shaped or spherical and is often referred to as a 'devil's egg'. Although the name is a bit misleading (as it does not have a hard shell), in this form it can reach up to 6 cm in diameter. When cut open, the fungus has three clearly distinguishable layers, with the middle layer being the beginning of the fruiting body. The second part of the name, 'smelly', refers to the odour emitted by mature specimens.

What smells so bad?

The smell is downright repulsive, cadaverous, often compared to carrion, faeces, or rotten cabbage. This smell is the result of the presence of sulphur compounds, mainly hydrogen sulphide, mercaptans and organic disulphides (e.g. dimethyl sulphide), which are formed in the slimy spore-bearing mass (soil). As reported by Liu [5], 102 volatile compounds were identified from Phallus impudicus fruiting bodies after breaking the shell. According to PC1 and PC2 on the PCA chart, they accounted for 95.49% and 2.07% of the total variance of volatile compounds, respectively. The volatile compounds in the stems of Phallus impudicus at different growth stages could be separated and showed significant differences. Differential volatile metabolites were obtained by OPLS-DA and PLS-DA, among which 50 metabolites with the highest VIP value clearly stood out at four different growth stages, especially from the rapid growth stage to the maturity stage, where almost all metabolites had the highest content at the maturity stage. Changes in volatile compounds were largely dependent on the growth stage and increased with the growth stage. It is noteworthy that the cracking of the fruit body shell was a critical turning point for the synthesis and accumulation of volatile compounds. Furthermore, volatile compounds, mainly containing 6-undecyl alcohol, α-terpine-7-al, 2, 4-decenol and 2-cyano-2-ethyl-butanamide, may co-regulate the formation of the aroma of Phallus impudicus during the growth phase through the synergistic action of other chemical components.

For most volatile compounds found in the stipe of Phallus impudicus, significant differences in relative content were observed in four different stages of development, especially in the last three stages. The volatile compounds with the highest relative content are 2-cyano-2-ethylbutyramide and 6-undecanol, followed by α-terpinene-7-al, 2, 4-decadienol and methyl geraniate, from the stage of shell cracking to the stage of maturity, ranging from 434.70 to 6154.87, 358.67-1822.92, 166.88-1217.01, 127.52-1216.42 and 6.86-956.79, respectively. Among these, 2-cyano-2-ethylbutyramide has not been reported in other edible fungi, which may indicate that it is a characteristic volatile component of Phallus impudicus. In addition, trans-anethole, p-acetyl ethyl benzene, 2-hexylpyridine, (E)-myroxyd, (E, E)-2,4-decadienal, verbenone, (E)-6-nonenal, citronellal, 4, 8-dimethyl-1, 3, 7-nonadiene, α-cyclocitral, butylbenzene, isopropyl benzoate, chrysanthenone, cis-anethole, perillic aldehyde, 5-undecanol and 2-phenylcrotonaldehyde with a relative content range of 1.27-947.02 also had a key influence on the composition of volatile components and the formation of the aroma of Phallus impudicus. The lowest relative content of volatile components observed in the stalk of Phallus impudicus in the last three stages was β-linalool and γ-muurolene, followed by β-ocimene, durene, 3-ethyl-3-methyldecane, anisole and p-hydroxyacetophenone, ranging from 3.83 to 5.76, 3.99-6.99, 0.16-7.38, 0.56-7.70, 0.39-9.47, 2.65-9.56 and 0.14-9.60, respectively. According to the semi-quantitative results obtained, with the exception of a slight accumulation of 14 metabolites (eremophilene, 3-o-tolylopentane, β-linalool, benzoic aldehyde, phenol, α-caryophyllene, α-zingiberene, 4-pentenyl propionate, (E)-carvone, γ-muurolene, α-muurolene, o-xylocinol, geranylacetone and α-2-propenylbenzenemethanol) in the budding phase, the remaining 88 metabolites were not detected at this stage, indicating that the production, accumulation and release of volatile compounds occurred mainly after the shell was broken by the fungal thallus. Dimethyl oligosulphides (including dimethyl disulphide and dimethyl trisulphide) were the main cause of the distinctive aroma of the mature fruiting body [6,3]. Adequate growth can improve the overall volatile compound content in the stem of Phallus impudicus, which largely determined the quality and nutritional value of this regional edible mushroom. Furthermore, the types and concentrations of volatile compounds in the edible mushroom Phallus impudicus depended mainly on the growth stage [6-8].

Is it edible?

Although the chemical composition of the mushroom described above could be a factor determining that it is inedible and cannot be used in any other way, this is not entirely true. Phallus impudicus is eaten at an early stage, when it is in the form of an egg, even raw, although it is more commonly pickled or made into an alcohol tincture. Adult fruiting bodies are inedible, although they are not poisonous. An adult phallus impudicus consists of a white, hollow stem with a porous surface and a bell- or thimble-shaped cap with a ribbed surface in an olive-green colour. It consists of a spore mass, which drips over time, attracting mainly flies with the smell of carrion and gas. It is the smell of carrion that deters adults from eating them. In some countries, such as France and Germany, mature fly agaric fruiting bodies are also eaten after the sticky mucus has been removed. They are even used as a spice.

In addition, P. impudicus has been used for centuries in traditional medicine, especially in Eastern Europe and China (as a mushroom with similar properties in Asia). It was used as a pain reliever, digestive aid, and in the treatment of gout and rheumatism (mainly in the form of a spirit tincture made from the gelatinous cover or egg). The properties of P. impudicus are compared to those of the Asian shiitake mushroom, including in terms of improving lipid profile and blood pressure. What is more, the stinkhorn is considered to have the strongest medicinal properties among European mushrooms. Tincture from young fruiting bodies was traditionally used for stomach aches, inflammation and stomach ulcers, kidney disease, gout, bronchial asthma and tuberculosis, for compresses for joint pain and rheumatism, and for washing wounds, including bedsores, bites, burns and infectious rashes.

What Phallus impudicus hides and whether time heals wounds?

Phytochemical studies indicate that extracts from P. impudicus are rich in polysaccharides (mainly β-glucans) [9]. These substances are being studied for their potential to stimulate the immune system (activation of lymphocytes and macrophages). The active compounds in P. impudicus also exhibit antiviral [10], antibacterial, antioxidant [2], anti-inflammatory and immunostimulatory [11] properties. This effect is due to the presence of valuable active compounds, including polysaccharides, glucans, polyphenols, phospholipids and peptides, as well as unsaturated fatty acids and fibre in the form of chitin [11].

According to various accounts from so-called folk or traditional medicine, tinctures, ointments and creams made using mostly alcoholic extracts from P. impudicus were successfully used to treat wounds of various origins. Wound healing promotion has been one of the most studied beneficial effects of mushrooms, described in different scientific literatures [12,13]. Mushrooms' medicinal properties are closely linked to its content in bioactive compounds, which mostly included polysaccharides, terpenoids, glucans, phenolic compounds, statins, lectins, among others. Melanin pigments, chitin and chitosan which are found in their cell wall along with extracellular enzymes are other effective molecules [14-16]. The wound healing properties of mushrooms include different mechanisms such as immune epithelial cells stimulation, and cytokines and growth factors release [17,18]. Thus, given the above listed aspects, the present review aimed to provide key insights on mushrooms nutritional value and composition, ethnobiology and ethnopharmacology, and wound healing potential.

The wound healing process begins almost immediately after the wound occurs. The regeneration of the epithelium and repair of the connective tissue of the skin occurs as a result of the joint action of blood cells, immune cells and various tissues. The blood entering the wound contains platelets, which aggregate to form a platelet plug, preventing further bleeding. Various enzymes responsible for the coagulation process are activated, resulting in the polymerisation of fibrinogen, which in turn leads to the formation of a gelatinous clot that serves to stick the edges of the wound together. Then, a mechanism of gradual healing, well organised in biological and temporal terms, takes place in the so-called phases of wound healing. Regardless of the type of wound and extent of tissue loss, the healing process proceeds in phases that overlap and often occur simultaneously. The distinction between the individual stages of healing only covers the essential morphological changes and does not fully reflect their complexity. Wound healing is usually divided into three or four phases:

- Exudative phase,
- Cleansing phase,
- Proliferative phase,
- Remodelling phase (wound contraction and scar formation).

The exudative phase usually lasts from 4 to 7 days and manifests itself, among other things, through active congestion in the area surrounding the damaged tissues, oedema, extravasation of granulocytes, lymphocytes, monocytes and plasma antibodies, production of cytokines and chemokines, as well as increased capillary permeability, which may result in the appearance of exudate. It is worth noting that the presence of exudate is desirable, although in order to prevent infection, the nature of the exudate, its colour, consistency and odour should be observed. The cleansing phase is classified by some experts as part of the exudative phase, although it can also be distinguished as a separate phase. Wound cleansing occurs approximately 4-7 days after the injury, when the inflammatory response gradually subsides and macrophages begin to dominate the wound, gradually eliminating all contaminants and microorganisms. The proliferative phase is the stage during which the damaged tissues heal properly. It usually lasts from 3 to 6 weeks, during which time the skin's productive cells, fibroblasts, become active, and at the same time, neovascularisation occurs. The remodelling phase lasts from 3 weeks to even several years, depending on the individual conditions of the patient and the type of wound. During this time, the scar is remodelled, becoming paler and flatter over time, and its mechanical strength increases. It has been found that the strength of the wound 1 week after injury is 3% of the strength of normal dermis, while after three months, the damage will have 80% of the strength of normal skin, with a significant increase in strength associated with remodelling. In this phase, the collagen structure is also reorganised, causing the wound environment to normalise and heal completely [19-22].

The most important secondary metabolite in medicinal mushrooms are polysaccharides, which belong to1,3-β-glucans family, having antitumor activities which are achieved by enhancing and blocking cellular immunity pathway. These polysaccharides exhibit antitumor and immunostimulant properties and generally, glucans with high molecular weight seem to be more effective as compared to low molecular weight. Biologically active polysaccharides have unique structures and they vary from strain to strain and species to species. Generally, the hot-water-soluble fractions from medicinal mushrooms are used to extract these polysaccharides to find out their pharmacological activity [11].

The study of the therapeutic effect of 10% P. impudicus polysaccharides ointment in a model of a full-thickness cutaneous wound in rats showed a pronounced wound-healing effect compared to the use of ointment base in control animals, which made it possible to shorten the periods of complete wound surface healing by 1.8 times. Thus, in the model of an acute full-thickness wound in rats, the ointment containing P. impudicus polysaccharides had a high therapeutic activity throughout all the phases of the wound process and accelerated the repair processes of the wound surface, causing faster maturation and remodelling of the granulation tissue, and also accelerated the recovery of the dermis, epithelial skin and its derivatives and shortened the periods required for complete healing of the wounds [23].

It was also showed that Diabetes mellitus is a metabolic disease accompanied by chronic hyperglycemia caused by absolute or relative insulin deficiency. Zakrzeska et al. showed the potential role of P. impudicus extract in accelerating wound healing in diabetic rats. For the induction of diabetes, streptozotocin (STZ, concentration 100 mg/mL) at a dose of 30 mg/kg b.w. in citrate buffer, pH 4.5 was used. Wounds were excised by cutting a 10-mm-diameter flap of full-thickness skin with a barb under inhalation anaesthesia and 5% isoflurane under aseptic conditions. Wounds were treated with a standard preparation and with a prototype product containing an alcoholic extract of P. impudicus. Several metabolites that promote wound healing, including amino acids, sugars, organic acids, and other compounds, were identified in the ethanolic extract by GC-MS. In the MTT assay, the alcoholic extract of P. impudicus was nontoxic and stimulated fibroblast proliferation, which was also expressed as an increase in DNA and collagen synthesis. A hydrogel containing an extract of the fungus P. impudicus was shown to accelerate the period of wound desquamation in the experimental animals compared to the control groups. There was also a statistically significant ($p > 0.005$) reduction in SOD activity and TBARS compared to the control group, indicating an intensive healing process in which oxidative enzyme systems play a significant role [24].

Unfortunately, in addition to its health-promoting properties, some studies also indicate its toxic effects. Cytotoxic properties of Phallus impudicus treatment were associated with a decrease in cellular metabolic activity, dysregulation of redox homeostasis and impairment of selected antioxidant cell protection systems. As a consequence, p53/p21- and p16-mediated cell cycle arrest followed by p27 activation is initiated. The observed changes were associated with telomere shortening and numerous DNA damage at the chromosome ends (altered expression pattern of TRF1 and TRF2 proteins), as well as upregulation of cleaved caspase-3 with a decrease in Bcl-2 expression, suggesting induction of apoptotic death. Thus, it's provided molecular evidence for mechanistic pathways and novel adverse outcomes linked to the Phallus impudicus treatment towards men's health and fertility reduction [25].

Reminiscences and remarks

Phallus impudicus seems to be a fungus that is both known and unknown, edible and inedible, intriguing and devilish. Nevertheless, it is very interesting and worthy of our greater attention. With the advancement of scientific research, numerous bioactive compounds extracted from fungi have come to be recognised as responsible for their biological and therapeutic properties, among which their anti-atherosclerotic, liver-protective, analgesic, anti-inflammatory, anti-diabetic and antioxidant effects stand out. There are also increasing reports of the potential of fungi in wound healing, due to their richness in polysaccharides and phenolic compounds. However, some species can cause extremely serious, sometimes fatal poisoning, which is why it is extremely important to deepen our knowledge in this field. Further research is therefore needed to evaluate the potential of bioactive compounds derived from fungi and their medicinal properties, as well as the extracts from which they are obtained. Nevertheless, the use of fungal ingredients and extracts in cosmetics can be considered a niche worth exploring due to their remarkable wound-healing properties.

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Conflict of interest

No conflict of interest.

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