Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Beyond Medicine: Reassessing Ötzi's Birch Polypore (Fomitopsis betulina) as a Multipurpose Biomaterial

Mariana Pelin Villani

marianapvillani@gmail.com

Royal Botanic Gardens, Kew

Research Article

Keywords: Tyrolean Iceman, ethnomycology, experimental archaeology, fungal biomaterials, fishing technology, material culture

Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11597114/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Beyond Medicine: Reassessing Ötzi's Birch Polypore (*Fomitopsis betulina*) as a Multipurpose Biomaterial

Mariana Pelin Villani[1,2]

[1] University of Gastronomic Sciences, Pollenzo, Italy

[2] Royal Botanic Gardens, Kew, Richmond, United Kingdom

Corresponding author: Mariana Pelin Villani, marianapvillani@gmail.com

Abstract

The Tyrolean Iceman, Ötzi, carried two fungal species among his equipment: *Fomes fomentarius* and *Fomitopsis betulina* (formerly *Piptoporus betulinus*). While the use of *F. fomentarius* as tinder is well established, the function of the shaped, bead-like *F. betulina* fragments, which were perforated and threaded onto leather thongs, remains uncertain. Previous interpretations have emphasised medicinal and symbolic functions, but the morphology and attachment of the fragments also invite consideration of their material properties and practical uses.

This study reassesses the fragments as possible functional biomaterials through a literature review and ethnomycological comparison, participant observation at archeoParc Schnalstal, collections-based research in the Economic Botany Collection at the Royal Botanic Gardens, Kew, and exploratory flotation trials. Historical records and Kew collection objects document the use of birch polypore for razor strops, abrasives, cork-like plugs, pin cushions, toys and fishing floats, demonstrating the diverse ways in which its material properties have been utilised.

The experimental trials showed that dried, shaped pieces of *F. betulina* is buoyant, can be attached to a line, remains intact after immersion, and can be dried and reused. The evidence demonstrates

that use as a fishing float and other practical interpretations are materially plausible and that the fragments are best considered within a wider field of fungal biomaterial uses rather than through an exclusively medicinal or symbolic interpretation.

Keywords: Tyrolean Iceman; ethnomycology; experimental archaeology; fungal biomaterials; fishing technology; material culture.

Introduction

The discovery of the Tyrolean Iceman in 1991 near Tisenjoch, in the Ötztal Alps, provided an exceptional window into Copper Age lifeways. Preserved for approximately 5,300 years in glacial ice, Ötzi was recovered with clothing, weapons, tools, containers and other organic materials, making him one of the most exceptionally preserved and extensively studied prehistoric individuals in Europe (Fleckinger 2011; Oeggl et al. 2007). His equipment reveals a highly mobile Alpine lifeway involving hunting, repair, fire-making, food preparation and movement across different ecological zones (Fleckinger 2011; Maixner et al. 2018; Oeggl et al. 2007). Evidence from his body and equipment further shows that his final days were marked by violent conflict, physical hardship and hurried movement through the Alps. He sustained a deep wound to his right hand shortly before his death and was later struck from behind by an arrow that lacerated the left subclavian artery, causing fatal bleeding at an altitude of approximately 3,210 m (Wierer et al. 2018).

Among the most remarkable items in this assemblage are the fungi he carried. Peintner et al. (1998) identified two polypore species in the Iceman's equipment: several processed pieces of *Fomes fomentarius* (L.) Fr., commonly known as tinder fungus, and two shaped fragments of *Fomitopsis betulina* (Bull.) B.K. Cui, M.L. Han & Y.C. Dai, the birch polypore. Within the circumstances of Ötzi's final journey, the presence of two deliberately selected, prepared and

transported fungal species is particularly significant for ethnomycology. It indicates that fungi were recognised and valued as portable resources within the practical equipment of a person travelling through a demanding environment more than 5,000 years ago. *Fomes fomentarius* belongs to Polyporaceae and *F. betulina* to Fomitopsidaceae; both are wood-decay fungi within Polyporales (Index Fungorum 2026a, 2026b).

The *F. fomentarius* fragments were found in Ötzi's girdle bag and showed evidence of deliberate mechanical preparation. Their felt-like structure, together with pyrite particles embedded among the hyphae, strongly supports their interpretation as tinder used for fire-making and possibly fire-carrying (Peintner et al. 1998). By contrast, the purpose of the *F. betulina* fragments remains uncertain. They were shaped into rounded, bead-like pieces, perforated, and threaded individually onto leather thongs (Peintner et al. 1998; Peintner and Pöder 2000).

Earlier interpretations favored medicinal and possibly symbolic explanations for the birch polypore fragments. This interpretation is plausible. *Fomitopsis betulina* has a long history in European and northern Eurasian ethnomedicine and has been investigated for antimicrobial, antiparasitic, antioxidant, and other pharmacologically relevant properties (Grienke et al. 2014; Wani et al. 2010). Peintner et al. (1998) and Peintner and Pöder (2000) considered the medicinal properties of the species relevant to interpreting Ötzi's fragments.

However, a medicinal interpretation should not exclude other functions. Birch polypores are not only medicines; they are also important materials. Their corky texture, durability, lightness, absorbency and workability have supported domestic, craft, technological and symbolic uses. The shaped form of Ötzi's *F. betulina* fragments and their attachment to leather thongs therefore warrant analysis as material features rather than incidental details.

This article reassesses Ötzi's birch polypore through an ethnomycological, collections-based and experimental-archaeological approach. It considers several practical interpretations of *F. betulina* as a biomaterial and uses the fishing-float hypothesis as an experimentally tested case. This hypothesis is supported by three lines of evidence: the morphology and attachment of the fragments resemble float technologies; ethnographic records document dried birch polypores used as floats for nets and lines (Svanberg 2018); and exploratory trials demonstrate that shaped pieces of dried *F. betulina* are buoyant, reusable and functional when attached to a fishing line. The article does not argue that fishing was the only or definitive function of the fragments. Rather, it evaluates flotation alongside other material possibilities, including strops, cork-like objects and garment toggles, and argues that the fragments may have belonged to a flexible, multipurpose material repertoire.

Previous Interpretations of Ötzi's Fungi

The two fungi carried by Ötzi appear to have occupied different technological roles. The *Fomes fomentarius* fragments were processed into a loose, felt-like material, that is called amadou in many parts of the world. Microscopic examination showed that this material consisted of loosely interwoven context hyphae lacking the compact structure of untreated fungal tissue, implying deliberate mechanical preparation (Peintner et al. 1998). The presence of pyrite particles embedded in the fungal tissue further supports the interpretation that *F. fomentarius* formed part of a fire-starting kit (Peintner et al. 1998). When used with pyrite and flint, prepared fungal tinder can catch sparks and produce embers, allowing fire to be started, carried, or rekindled.

This interpretation is consistent with broader ethnomycological evidence. *F. fomentarius* has been widely used as tinder and fire-carrying material across Europe, northern Eurasia, and North America (Peschel 1998; Svanberg 2018). In Italy, its association with fire is reflected in

vernacular names such as *fungo ignario*, or “fire fungus” (Comandini et al. 2018). In Sardinia, shepherds and peasants used *F. fomentarius* as tinder, with numerous dialectal names reflecting its importance in daily life (Comandini et al. 2018). Among Sami and Scandinavian communities, *F. fomentarius* was also used to carry fire over long distances, as its prepared trama could smolder slowly and safely (Svanberg 2018). During participant observation at ArcheoParc Schnalstal, where this technique is demonstrated several times each day, the author learned and repeatedly practiced fire-making with flint, pyrite and amadou alongside the park’s demonstrators. The author now incorporates this technique into public presentations, helping audiences understand in practical terms how fungi served as important technological allies by making sparks easier to catch and preserve as embers.

The birch polypore fragments, by contrast, have a much tougher consistency and were shaped into rounded, bead-like pieces, perforated, and threaded individually onto leather thongs.



Fig. 1.

Peintner et al. (1998) and Peintner and Pöder (2000) considered several possible functions for the *F. betulina* pieces. A nutritional role was considered improbable because of the corky texture of old basidiomes, as well as the counterintuitive nature of suspending small food portions on leather thongs. On balance, the authors favored a medicinal-symbolic interpretation, situating the fragments within broader ethnomycological patterns in which polypores with medicinal properties may also be attributed symbolic or protective value (Blanchette 1997; Blanchette et al. 1992; Peintner and Pöder 2000; Peintner et al. 1998).

This interpretation is reasonable, but the emphasis on medicine and symbolism and the disregard for their shape may have narrowed consideration of other material uses. The birch polypore fragments were shaped, perforated, and threaded onto leather thongs. This arrangement indicates care, intent, and portability. The fragments were not loose scraps, nor were they stored in the same manner as the processed tinder fungus. Their shapes and manner of attachment suggest that Ötzi may have recognized specific material properties in these fungal bodies.

The medicinal, ethnomycological and archaeological evidence relevant to these material hypotheses is presented together in the Results, beginning with the wider biomaterial uses of *F. betulina* before considering fishing flotation as one specific possibility.

Materials and Methods

Literature Review and Ethnomycological Comparison

This study combines published archaeological literature on Ötzi's fungal assemblage with ethnomycological literature on the documented uses of *Fomitopsis betulina* and *Fomes fomentarius*. Particular attention was given to records describing the physical and technological uses of polypores, including applications as tinder, strops, polishing materials, cork-like bottle plugs, pin cushions, toys, garment fittings and fishing floats. The aim was not to claim direct

cultural continuity between Copper Age Alpine communities and other European traditions, but to evaluate whether the physical properties of *F. betulina* support plausible material interpretations.

The broader review drew on archaeological, ethnomycological and experimental-archaeology sources relating to Ötzi, Alpine lifeways, fishing technologies and traditional uses of polypores. Priority was given to peer-reviewed articles, scholarly books and museum or institutional sources. Ethnographic analogy was treated cautiously: later historical records cannot be projected directly onto Ötzi's cultural context, but they can demonstrate material possibilities when they describe uses based on properties such as buoyancy, texture, durability, workability and ease of attachment.

Participant Observation and Site-Based Research

Participant observation was undertaken from April to June 2025 during an extended placement at ArcheoParc Schnalstal in South Tyrol, Italy. The research focused on how Ötzi's equipment and Copper Age plant- and fungus-derived materials were interpreted, reproduced and handled within an experimental-archaeology setting. The author worked as an active participant alongside ArcheoParc employees and demonstrators, assisting with daily work, material experimentation, demonstrations and public-facing interpretation. Contextual observations relevant to fungal tinder, cordage, flotation and other organic technologies were recorded throughout the placement. These observations helped frame the flotation trial in relation to embodied practice, reuse and maintenance rather than as an isolated laboratory test.

A contextual visit to the South Tyrol Museum of Archaeology in Bolzano was also undertaken to review the public display and interpretation of Ötzi's clothing, equipment and fungal materials. The original archaeological fungal fragments were not directly sampled as part of this study.

Collections-Based Research at the Economic Botany Collection

Collections-based research was undertaken in September and October 2026 during a placement in the Economic Botany Collection at the Royal Botanic Gardens, Kew. The broader fungal holdings were reviewed, followed by a targeted search of catalogue information for historical *F. betulina* objects associated with practical material uses. Selected objects were visually examined and photographed together with their labels and catalogue records. Observations focused on taxonomic attribution, form, processing, attachment or mounting, condition, provenance, attributed use and material properties.

Particular attention was given to two objects catalogued as razor strops (catalogue nos. 30253 and 38200). The objects were treated as comparative material evidence showing how *F. betulina* has been transformed into functional objects, rather than as direct cultural analogues for the Copper Age fragments.

Experimental Trials

Preliminary experimental trials were conducted using dried pieces of *Fomitopsis betulina* shaped to approximate the size and general morphology of Ötzi's birch polypore fragments. The experiments were exploratory and intended to test material feasibility.

The fruiting body from which the experimental pieces were prepared was collected by the author during fieldwork in the Alps. It was identified as *F. betulina* on the basis of its diagnostic macromorphological characteristics and its occurrence on birch substrate (Fig. 2). The specimen has subsequently been accessioned into the Economic Botany Collection at the Royal Botanic Gardens, Kew, under catalogue no. XXXXX.



Fig. 2

The first trial was conducted at ArcheoParc Schnalstal in South Tyrol, Italy. A dehydrated, shaped piece of *F. betulina* was threaded with lime-bast cord and placed in the ArcheoParc pond. The trial was designed to observe buoyancy, water absorption, durability, interaction with the pond environment and post-immersion drying. After the flotation period, the specimen was dried while suspended on a thread to assess whether it retained its form and could plausibly be reused.

The second trial was conducted in Marília, Brazil, in an active fishing context. A shaped piece of dried *F. betulina* was coated with beeswax to test whether natural waterproofing could prolong buoyancy during fishing activity. The fungal float was attached to a modern nylon fishing line and used with a bamboo fishing pole. Modern line was used because no Copper Age fishing-line replica was available at the time. Flotation time, water absorption, durability and practical functionality were observed.

Ethical Considerations

This research was conducted in accordance with the University of Gastronomic Sciences Code of Ethics and the *Ethnomycology Ethical Guidelines* of the Fungi Foundation (Villani et al. 2023). Ethical considerations centered on respectful collaboration, informed consent, reciprocal knowledge exchange and responsible sharing of knowledge.

The research was developed collaboratively with the ArcheoParc community. The author worked as an active participant alongside employees and demonstrators, assisting with daily work, experimental activities and public interpretation. Participation and discussion were voluntary and based on ongoing mutual agreement. No identifiable personal information or attributed statements are reported. Findings were shared with the ArcheoParc community to support continuing knowledge exchange. The original archaeological objects and the Kew collection objects were not sampled or altered.

Results

Ethnomycological Uses of *Fomitopsis betulina* as a Biomaterial

The literature review confirms that *Fomitopsis betulina* has been used not only as medicine but also as a practical biomaterial (Peintner and Pöder 2000; Papp et al. 2017; Pleszczyńska et al. 2017; Svanberg 2018). Documented applications include razor strops, natural abrasives, polishing materials, cork-like bottle plugs, pin cushions, toys and protective objects (Camangi et al. 2008; Papp et al. 2017; Svanberg 2018; Svanberg and Lidström, 2019). These uses draw upon different combinations of the fruiting body's physical properties, including its softness when fresh, corkiness and lightness when dry, workability, absorbency, resilience and durability.

The surface of the fruiting body was used as a strop for finishing razor edges, and strips of the fungus served as natural abrasives and polishing materials (Camangi et al. 2008; Grienke et al.

2014; Svanberg 2018). Linnaeus recorded dried fruiting bodies used as cork-like bottle plugs, a use reflected in the Swedish vernacular name *korksopp*, or "cork fungus" (Linnaeus 1755, cited in Svanberg 2018). Birch polypores were also fixed to walls as pin cushions, carved into balls and doll heads, and used as protective objects in domestic and agricultural settings (Grienke et al. 2014; Svanberg 2018; Svanberg and Lidström, 2019).

These examples demonstrate that birch-polypore fruiting bodies have been deliberately selected, cut, pierced, shaped, mounted and reused as functional objects. They also show that the same organism may serve medicinal, domestic, technological and symbolic purposes, and that these categories are not necessarily mutually exclusive. This broader material versatility is important when interpreting Ötzi's shaped and perforated fragments, which should not be considered only within medicinal or symbolic frameworks.

A further functional interpretation was proposed by Kuiken and Kuyper (2020), who suggested that the two birch-polypore objects may have served as buttons or toggles fastening Ötzi's separate leggings to his waist belt. Their interpretation rests principally on the objects' attachment to leather thongs and their observation that no other fasteners connecting the leggings to the belt had been identified. They proposed that the fruiting bodies may have been pierced and threaded while moist, with shrinkage during drying securing them more firmly around the thongs. However, the study reports neither a direct experimental test of this mechanism nor a full-scale reconstruction showing how the fungal pieces would have connected the leggings to the belt, passed through corresponding loops, or withstood repeated movement and loading. Contraction of the fruiting body during drying would not necessarily cause an existing perforation to tighten: depending on the organisation and orientation of the fungal tissue, the opening might narrow, retain its dimensions, become distorted or enlarge. The comparatively large dimensions of the

pieces may also have made them cumbersome as clothing fasteners, although this requires experimental evaluation. Kuiken and Kuyper themselves acknowledge that further investigation of the mechanical properties of *F. betulina* fruiting bodies is required.

The reconstruction displayed at archeoParc Schnalstal presents a different possible arrangement, in which the birch-polypore objects hang freely from Ötzi's belt alongside the perforated stone disc and leather thongs reconstructed as a bird-carrying tassel, rather than fastening the leggings (Fig. 3). Although this modern reconstruction cannot establish the objects' original position, it illustrates an alternative placement compatible with their attachment to leather thongs. Earlier clothing reconstructions and the interpretation presented by the South Tyrol Museum of Archaeology also show the leggings secured to the waist belt using knotted leather strips (South Tyrol Museum of Archaeology n.d.). A simple adjustable knot could therefore have provided a secure and releasable fastening without requiring separate fungal components. This does not exclude the possibility that the fungal objects served as toggles, but the interpretation remains experimentally unverified and would benefit from wetting-and-drying trials, mechanical testing and full-scale clothing reconstruction.



Fig. 3

Birch Polypore as a Fishing Float

An especially relevant material use of *F. betulina* is its role in fishing technology. Svanberg (2018), citing Rothof's *Hushålls-Magasin* of 1762, records that well-dried birch conks were tied to fishing nets and lines to serve as floats. This practice took advantage of the fungus's cork-like structure, low density and buoyancy. The vernacular association between birch polypore and cork further indicates the historical recognition of these material properties (Svanberg 2018).

This evidence does not come from the Copper Age Alps and cannot be used as direct proof of Ötzi's practice. Nevertheless, it demonstrates that birch polypore can be—and historically has been—used as a fishing float. Ethnomycological analogy is valuable when applied cautiously because different communities may independently recognise and use materials according to similar physical properties. A dried polypore that is light, buoyant, durable, easily pierced and readily

attached to cordage may therefore be recognised as useful for floating nets, lines or other objects in different cultural and historical contexts.

The ethnomycological record does not establish cultural continuity between eighteenth-century Sweden and Copper Age South Tyrol. Instead, it demonstrates material possibility. The documented use of *F. betulina* as a fishing float makes it reasonable to investigate whether the shaped, perforated fragments threaded onto leather thongs and carried by Ötzi could have performed a comparable function.

Fishing and Fiber Technologies in the Archaeological Context

The literature reviewed did not identify any published study directly linking Ötzi himself to fishing, while published analyses of his stomach contents have not reported fish consumption during his last meal (Maixner et al. 2018). Nevertheless, the broader Alpine and European archaeological record shows that aquatic resources were exploited during prehistory and that fishing formed part of the technological world of communities practising farming, hunting, gathering and seasonal movement.

Earlier Mesolithic sites in the Adige Valley, including Galgenbühel/Dos de la Forca, provide evidence of seasonal occupation by hunter-gatherer-fishers (Wierer et al. 2016). More substantial material evidence comes from waterlogged pile-dwelling settlements around Alpine lakes, where exceptional preservation has revealed fishing equipment, faunal remains and other evidence of aquatic-resource use (UNESCO World Heritage 2019). Comparative evidence from elsewhere in Neolithic Europe further demonstrates the importance of fishing within farming societies. At Vinča-Belo Brdo in Serbia, lure hooks attest to innovative fishing technologies (Cristiani et al. 2016), while evidence from Scandinavia indicates that fishing remained significant within complex village economies despite agricultural intensification (Nielsen 2022).

These examples caution against assuming that farming communities did not exploit aquatic resources. They also demonstrate that fishing technologies—including nets, lines, hooks, floats and weights—formed part of the wider technological landscape of prehistoric Europe.

Ötzi's assemblage included numerous plant-fiber and leather technologies. Bast fibers were used for stitching, binding, containers, sheaths and other equipment, demonstrating the importance of cordage and fiber-working within his technological repertoire (Fleckinger 2011; Pfeifer and Oeggl 2000). His clothing and equipment also combined materials derived from domestic and wild animals, illustrating a flexible material culture drawing upon both managed herds and hunted animals (Fleckinger 2011; O'Sullivan et al. 2016). Public museum and experimental-reconstruction sources additionally describe cordage fragments and possible net-like structures among the objects associated with Ötzi's assemblage (ArcheoParc Schnalstal n.d.; South Tyrol Museum of Archaeology n.d.).

The presence of cordage and possible netting does not in itself demonstrate fishing, since nets and related fiber technologies may also be used for carrying, trapping, hunting, storage or repair. Nevertheless, these materials show that Ötzi's technological repertoire included the skills and materials required for net-based or line-based activities. The shaped and perforated birch-polypore fragments, threaded onto leather thongs, fit materially within this broader assemblage of cordage, knots, bindings and portable objects.

Other objects in the assemblage may also be relevant, although their functions remain uncertain. A hook-like bone awl could have served several purposes, including piercing, repair and the manipulation of fibers (Fleckinger 2011; South Tyrol Museum of Archaeology n.d.); its possible use as a fishing hook remains speculative. Similarly, the perforated dolomite stone disc with twisted hide tassels, commonly interpreted as part of Ötzi's small-game carrying equipment,

305 may reflect more general strategies for transporting hunted or fished animals (Fleckinger 2011;
306 South Tyrol Museum of Archaeology n.d.).



307

308 Fig. 4

309 Taken together, these sources show that *F. betulina* was historically employed as a versatile
310 biomaterial, including as a fishing float; that fishing technologies formed part of the wider
311 prehistoric Alpine and European material landscape; and that Ötzi possessed cordage, fiber-
312 working knowledge and portable equipment compatible with line- or net-based activities. The

fishing-float interpretation should therefore be understood as one specific possibility within a broader pattern of fungal biomaterial use and as a hypothesis suitable for experimental evaluation.

Historical Birch-Polypore Objects at Kew

The Economic Botany Collection at the Royal Botanic Gardens, Kew, contains object-based evidence that fruiting bodies of *Fomitopsis betulina* were deliberately cut, shaped and used as working materials. Catalogue no. 30253 (Fig.5) is a thick, approximately rectangular razor strop with a broad, flattened working surface. Portions of the darker pileus surface remain along its margins. A lateral recess is present at one end, and a metal nail inserted into the underside suggests that the object may once have been attached to a handle, base or other supporting component. Its historical label identifies it as a razor strop made from *Polyporus betulinus*, a name formerly applied to *F. betulina*, and associates it with Helsingfors and Dr Nordenskiöld, which suggests that the object probably dates to around 1857.



Fig. 5

Catalogue no. 38200 (Fig. 6) is a specimen of *F. betulina* collected from dead birch in Merionethshire, Wales. Its label states that the fungus was “used locally as a razor strop” and records its donation by Lady Bradford, O.B.E., in 1927 (Royal Botanic Gardens, Kew 2026). Together, the two objects document the use of birch-polypore tissue as a razor-stropping material in two distinct geographical contexts.



Fig. 6

Catalogue no. 30298 (Fig. 7) was accessioned in 1895 and is recorded as having been donated by the British entomologist W. F. H. Blandford. Catalogued under the historical name *Piptoporus betulinus*, it is described as a slice “used for labels and mounts for entomological subjects.” The surviving slice bears a printed grid listing collecting localities and months and repeatedly names J. J. Walker, a British entomologist and Royal Navy engineer who collected extensively in Australia, China and other regions. The object demonstrates that birch-polypore tissue could be cut into thin, flat and regular pieces that provided a surface for printed information and served as labels or mounts in natural-history collections.

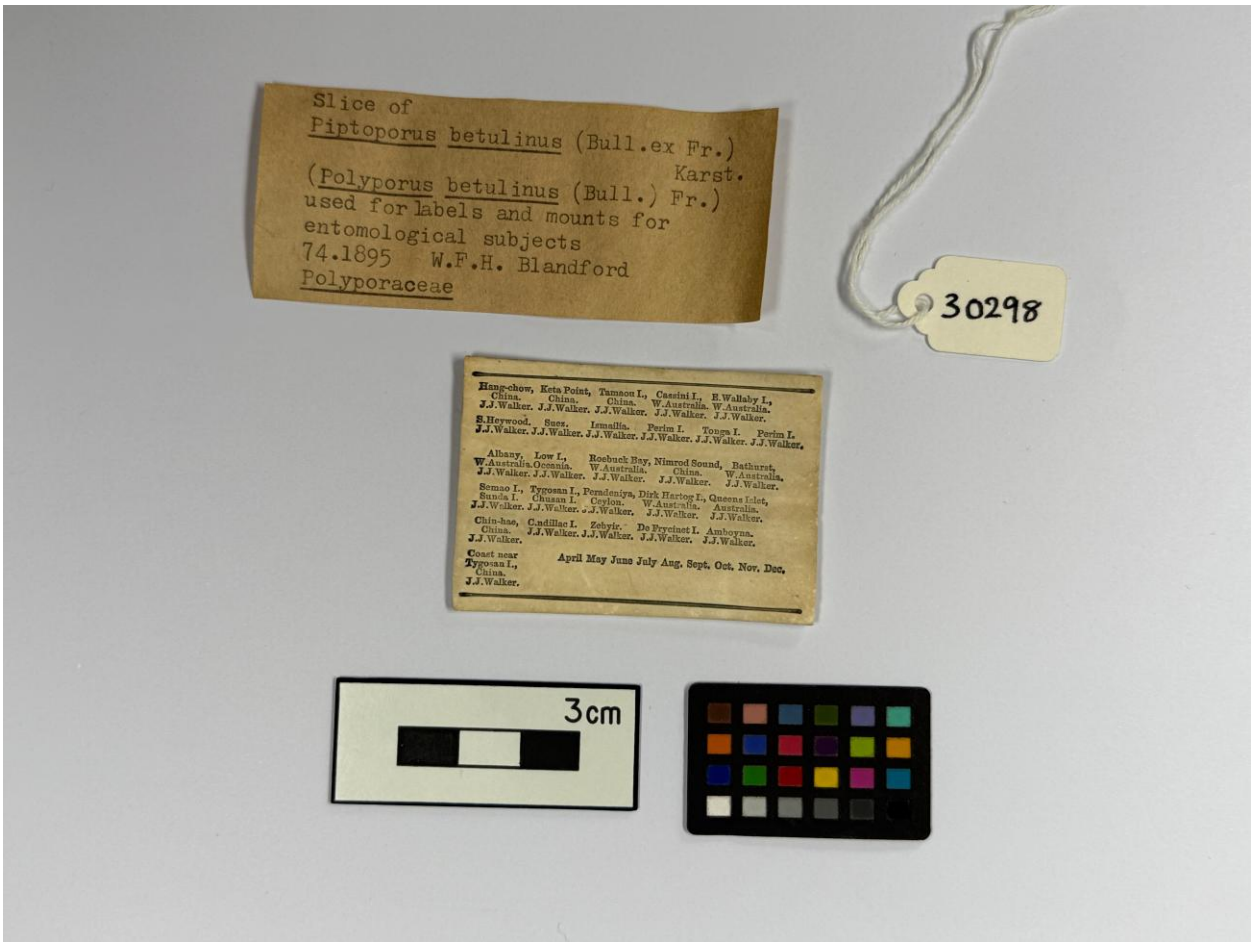

Fig. 7

Collectively, these objects show that *F. betulina* was not merely collected as a biological specimen but was deliberately processed into functional objects that made use of its firmness, workability and capacity to be cut into different forms.

Flotation Trial at ArcheoParc Schnalstal

The first experimental trial demonstrated that a dried, shaped piece of *Fomitopsis betulina* could remain buoyant for several hours. When placed in water at ArcheoParc Schnalstal, the fungal body floated for approximately five hours. During this period, it remained on the water surface despite intermittent disturbance at the public pond and contact with pond organisms, including

tadpoles and insects. The attraction of flies and tadpoles to the floating fungus was observed (Fig. 8).



Fig.8

After removal from the water, the polypore was dried again while suspended on a thread. Once dry, it retained its shape and was suitable for reuse. This result is relevant because Ötzi's original fragments were perforated and threaded onto leather thongs. Suspension may have facilitated drying, transport, and repeated access after wet use.

Fishing Trial in Brazil

The second trial tested the fungal float in an actual fishing context in Brazil. The birch polypore was attached to a fishing line and treated with beeswax to improve water resistance. In this context, the float remained buoyant for approximately two hours before the wax coating began

365 to wear and the fungus absorbed water. Once saturated, the polypore sank and could function more
366 like a weight than a float.

367 However, the spongy structure of the fungus allowed water to be squeezed out manually.
368 After the water was pressed out, the fruiting body floated again. This process could be repeated
369 several times during bait replacement, extending the functional lifespan of the float. During the
370 trial, eight fish were caught over approximately three hours, demonstrating that the fungal float
371 was not merely theoretically viable but practically functional under the conditions tested. Even
372 after extended use, the fruiting body remained intact and could be dried for reuse.



373

374 Fig. 9

375 These experiments suggest that *F. betulina* can operate as a reusable fishing float,
376 especially when dried, suspended, and periodically maintained. The leather-thong suspension of

Ötzi's specimens may therefore be significant. Such an arrangement would allow the polypores to be carried, dried after use, and reused. The same feature previously interpreted as unusual or non-utilitarian may instead be consistent with a practical cycle of wetting, drying, transport, and redeployment.

Discussion

The interpretation of Ötzi's birch polypore should remain cautious. Medicinal use is plausible in light of ethnomycological and pharmacological evidence, although the presence of bioactive compounds does not demonstrate the function of the archaeological fragments (Grienke et al. 2014; Peintner and Pöder 2000; Peintner et al. 1998; Wani et al. 2010). Symbolic or protective significance is also possible (Blanchette 1997; Blanchette et al. 1992). The fishing-float hypothesis adds a material dimension to this debate, but it should be considered alongside other practical interpretations rather than as a definitive replacement for them.

The strongest evidence for the float hypothesis lies in the convergence of morphology, material properties, ethnographic analogy, and experimental performance. Ötzi's *F. betulina* pieces were shaped and threaded; dried birch polypore is buoyant; historical sources document its use as a fishing float (Svanberg 2018); and preliminary experimental trials confirm that it can function effectively in that role. None of these points alone is decisive. Together, however, they justify treating the hypothesis as plausible.

This reassessment also raises a broader methodological point. Archaeological fungi are often interpreted through a narrow set of categories: food, medicine, poison, tinder, or ritual object. Yet ethnomycological records show that fungi have also served as much more such as textiles, abrasives, cork-like bottle plugs, toys, ornaments, repellents, veterinary treatments, fermentation agents, and technical materials (Camangi et al. 2008; Comandini et al. 2018; Grienke et al. 2014;

Svanberg 2018; Svanberg and Lidström, 2019). Polypores in particular occupy a complex space in ethnomycology. Their bodies can be cut, dried, softened, hardened, threaded, burned, powdered, or worn. They are simultaneously biological, technological, medicinal, and symbolic.

Ötzi's fungal assemblage illustrates this complexity. *Fomes fomentarius* was almost certainly part of his fire technology, but even that species has wider uses such as medicinal, craft, apicultural, and ritual uses in ethnographic records (Comandini et al. 2018; Peschel 1998; Svanberg 2018). *Fomitopsis betulina* may likewise have had more than one function.

The Kew razor strops and the toggle hypothesis proposed by Kuiken and Kuyper (2020) reinforce this broader biomaterial framing. The strops show that birch polypore fruiting bodies could be deliberately shaped, finished and mounted to exploit their mechanical properties. This also makes edge maintenance a category worth considering. The toggle hypothesis similarly takes the form and leather attachment of the fragments seriously, but requires full-scale reconstruction and mechanical testing. Float, strop and toggle interpretations are therefore best treated as testable material hypotheses that may reveal different uses of a versatile fungus; they need not be understood as mutually exclusive across Ötzi's lifetime.

The context of Ötzi's final days also matters. Pollen analysis suggests that he moved rapidly across ecological zones in the approximately 33 hours before his death, descending into lower woodlands before reascending above 3,000 m near Tisenjoch (Oeggl et al. 2007). Biomolecular and microstructural analyses of his gastrointestinal tract indicate that he consumed a fat-rich meal of wild meat and cereals shortly before death, consistent with the energetic demands of high-altitude travel (Maixner et al. 2018). In such a context, lightweight, multipurpose materials would have been especially valuable. A birch polypore fragment could potentially serve as

medicine, strop or abrasive, cork-like object, float, toggle or another emergency material depending on need.

F. fomentarius and *F. betulina* are wood-decay fungi that participate in nutrient cycling, decomposition, and forest regeneration, while also providing medicine, tinder, smoke, and materials. Interpreting Ötzi's fungi as multipurpose biomaterials therefore connects prehistoric subsistence technologies with broader questions of ecological knowledge and sustainable material use.

At the same time, this broader framing should not obscure the main claim of this article. The present study does not argue that *F. betulina* was definitively used by Ötzi for fishing. It argues that such use is materially feasible, ethnographically documented, and consistent with the morphology and suspension of the fragments. The hypothesis should therefore be included among plausible interpretations of Ötzi's birch polypore.

Limitations and Future Research

The fishing-float hypothesis remains preliminary. The trials were exploratory, practice-based experiments rather than controlled laboratory tests or exact reconstructions.

Ethnographic analogy demonstrates possibility rather than cultural continuity. Direct analysis of the original fragments would be needed to distinguish among proposed functions Direct analysis of the original fragments would be needed to distinguish among the proposed functions, although deterioration over time may limit the conclusions that can be drawn. Fishing in Ötzi's immediate assemblage also remains unproven: cordage, possible net-like material and a hook-like awl establish technological plausibility but not activity. Future work should therefore combine comparative experiments, full-scale reconstructions and non-destructive analysis of the archaeological pieces.

Conclusion

Ötzi's birch polypore fragments remain among the most intriguing organic artefacts in his assemblage. Earlier interpretations have emphasised medicinal and symbolic significance, but their shaped, perforated form and attachment to leather thongs also require attention to material properties. Historical and ethnomycological evidence documents *Fomitopsis betulina* as a strop, abrasive, cork-like object, pin cushion, toy and fishing float, while another material hypothesis proposes its use as a garment toggle. Collections-based research at Kew provides physical examples of fruiting bodies deliberately shaped and mounted as working objects.

The experimental trials add a more specific finding: similarly shaped dried fruiting bodies can remain buoyant, be attached to lines, assist in fishing and be dried for reuse. This does not prove that Ötzi used the fragments as floats, but it establishes the material feasibility of the hypothesis and makes it appropriate for consideration alongside other interpretations.

The wider conclusion is therefore not that one practical explanation has replaced another. Rather, *F. betulina* should be approached as a potentially multipurpose biomaterial whose usefulness arose from its corkiness, lightness, workability, absorbency, resilience and capacity to be cut, pierced, suspended and reused, and its medicinal qualities. This perspective better reflects the versatility of fungi in human material culture and the ecological knowledge embedded in Copper Age lifeways.

Acknowledgments

The author thanks the ArcheoParc Schnalstal community, its employees and demonstrators, for supporting the participant observation, experimental and educational work related to Ötzi's fungi; the Master in Agroecology and Food Sovereignty of the University of Gastronomic Sciences for making this research possible; the South Tyrol Museum of Archaeology

468 for making information on Ötzi's equipment publicly available; GW4+ NERC UKRI for the
469 essential support during the Economic Botany Collection placement; and the Economic Botany
470 Collection at the Royal Botanic Gardens, Kew, for access to historical birch-polypore objects and
471 their documentation.

472

Literature Cited

ArcheoParc Schnalstal. n.d. Exhibition materials and on-site information panels. Madonna di Senales, South Tyrol, Italy: ArcheoParc Museum.

Blanchette, R. A. 1997. *Haploporus odorus*: A sacred fungus in traditional Native American culture of the northern plains. Mycologia 89(2): 233–240.

Blanchette, R. A., B. D. Compton, N. Y. Turner, and R. L. Gilbertson. 1992. Nineteenth century shaman grove guardians carved from *Fomitopsis officinalis* sporophores. Mycologia 84(1): 119–124.

Camangi, F., A. Stefani, L. Sebastiani, A. Lippi, P. Petrucci, and N. Falaschi. 2008. Etnomicologia: La risorsa fungo in Alta Valle del Vara—"La valle del biologico." Pisa, Italy: Scuola Superiore Sant'Anna; Gruppo Micologico Lucchese "B. Puccinelli."

Comandini, O., S. Paulis, and A. C. Rinaldi. 2018. Sardinia: Mycovisions from a charming land. Current Research in Environmental & Applied Mycology 8(5): 474–491. [https://doi.org/10.5943/cream/8/5/1]

Cristiani, E., V. Dimitrijević, and S. Vitezović. 2016. Fishing with lure hooks at the Late Neolithic site of Vinča-Belo Brdo, Serbia. Journal of Archaeological Science 66: 23–34. [https://doi.org/10.1016/j.jas.2015.11.005]

Fleckinger, A. 2011. Ötzi, the Iceman: The full facts at a glance. Vienna, Austria: Folio Verlag.

Grienke, U., M. Zöll, U. Peintner, and J. M. Rollinger. 2014. European medicinal polypores: A modern view on traditional uses. Journal of Ethnopharmacology 154(3): 564–583. [https://doi.org/10.1016/j.jep.2014.04.030]

Index Fungorum. 2026a. *Fomes fomentarius* (L.) Fr. Index Fungorum record 194860. Royal Botanic Gardens, Kew. Accessed August 14, 2026.

Index Fungorum. 2026b. *Fomitopsis betulina* (Bull.) B.K. Cui, M.L. Han & Y.C. Dai. Index Fungorum record 812646. Royal Botanic Gardens, Kew. Accessed August 14, 2026.

Kuiken, H., and Th. W. Kuyper. 2020. L'uomo del Similaun e il poliporo della betulla: Una nuova ipotesi. Bollettino del Gruppo Micologico G. Bresadola (n.s.) 61–63(1–3): 85–102.

Maixner, F., D. Turaev, A. Paladin, A. Leidinger, A. Herzog, S. Treffkorn, and A. Zink. 2018. The Iceman's last meal consisted of fat, wild meat, and cereals. Current Biology 28(14): 2348–2355.e9. [https://doi.org/10.1016/j.cub.2018.05.067]

Nielsen, S. 2022. From foragers to fisher-farmers: How the Neolithisation process affected coastal fisheries in Scandinavia. Open Archaeology 8(1): 956–986. [https://doi.org/10.1515/opar-2022-0263]

Oeggl, K., W. Kofler, A. Schmidl, J. Dickson, E. Egarter-Vigl, and O. Gaber. 2007. The reconstruction of the last itinerary of "Ötzi," the Neolithic Iceman, by pollen analyses from sequentially sampled gut extracts. Quaternary Science Reviews 26(7–8): 853–861. [https://doi.org/10.1016/j.quascirev.2006.12.007]

O'Sullivan, N., M. Teasdale, V. Mattiangeli, et al. 2016. A whole mitochondria analysis of the Tyrolean Iceman's leather provides insights into the animal sources of Copper Age clothing. Scientific Reports 6: 31279. [https://doi.org/10.1038/srep31279]

Papp, N., K. Rudolf, T. Bencsik, and D. Czégényi. 2017. Ethnomycological use of *Fomes fomentarius* (L.) Fr. and *Piptoporus betulinus* (Bull.) P. Karst. in Transylvania, Romania. Genetic Resources and Crop Evolution 64(1): 101–111. [https://doi.org/10.1007/s10722-015-0335-2]

Peintner, U., R. Pöder, and T. Pümpel. 1998. The Iceman's fungi. Mycological Research 102(10): 1153–1162. [https://doi.org/10.1017/S0953756298006546]

519 Peintner, U., and R. Pöder. 2000. Ethnomycological remarks on the Iceman's fungi. In: The
520 Iceman and his natural environment: Palaeobotanical results, eds. G. Bortenschlager and K.
521 Oeggl, 143–150. Vienna, Austria: Springer. [https://doi.org/10.1007/978-3-7091-6758-8_12]
522 Peschel, K. 1998. Puhpowee for the people: The uses of mushrooms by the Anishinaabe. Midwest
523 Ethnobotany Press.
524 Pfeifer, K., and K. Oeggl. 2000. Analysis of the bast used by the Iceman as binding material. In:
525 The Iceman and his natural environment: Palaeobotanical results, eds. G. Bortenschlager and
526 K. Oeggl, 69–76. Vienna, Austria: Springer. [https://doi.org/10.1007/978-3-7091-6758-8_6]
527 Pleszczyńska, M., M. K. Lemieszek, M. Siwulski, A. Wiater, W. Rzeski, and J. Szczodrak. 2017.
528 *Fomitopsis betulina* (formerly *Piptoporus betulinus*): The Iceman's polypore fungus with
529 modern biotechnological potential. World Journal of Microbiology and Biotechnology 33: 83.
530 [https://doi.org/10.1007/s11274-017-2247-0]
531 Royal Botanic Gardens, Kew. 2026. Economic Botany Collection: *Fomitopsis betulina* objects,
532 catalogue nos. 30253 and 38200. Object labels and collection records. Richmond, United
533 Kingdom.
534 South Tyrol Museum of Archaeology. n.d. Equipment. Bolzano, Italy: South Tyrol Museum of
535 Archaeology. Accessed August 14, 2026.
536 Svanberg, I. 2018. Ethnomycological notes on *Haploporus odorus* and other polypores in northern
537 Fennoscandia. Journal of Northern Studies 12(1): 73–91.
538 Svanberg, I. and Lidström, I. (2019). Viking games and Sámi pastimes: making balls of *Fomitopsis*
539 *betulina*. *Ethnobiology Letters*, 10(1), 86-96. https://doi.org/10.14237/ebl.10.1.2019.1565

University of Gastronomic Sciences. 2024. Code of Ethics. Pollenzo, Italy: University of Gastronomic Sciences. [https://www.unisg.it/assets/Codice-etico_Unisg_L.240-2010-CE_18-07-2024-English-Version-1.pdf]. Accessed October 13, 2026.

UNESCO World Heritage. 2019. Prehistoric pile dwellings around the Alps. Accessed August 14, 2026.

Villani, M., C. Moreno, and G. Furci. 2023. *Ethnomycology Ethical Guidelines*. Santiago, Chile: Fungi Foundation. [https://assets.ffungi.org/ethicalguidelines.pdf]. Accessed October 13, 2026.

Wani, B. A., R. H. Bodha, and A. H. Wani. 2010. Nutritional and medicinal importance of mushrooms. Journal of Medicinal Plants Research 4(24): 2598–2604. [https://doi.org/10.5897/JMPR09.565]

Wierer, U., L. Betti, M. Gala, A. Tagliacozzo, and P. Boscato. 2016. Seasonality and function of Mesolithic valley-bottom sites: Results from Galgenbühel/Dos de la Forca, Adige Valley (South Tyrol, Italian Alps). Quaternary International 423: 102–122. [https://doi.org/10.1016/j.quaint.2015.12.009]

Figure Captions

Fig. 1 Two shaped fragments of *Fomitopsis betulina* associated with Ötzi's equipment, perforated and threaded onto hide thongs. © South Tyrol Museum of Archaeology / Harald Wisthaler

Fig. 2 Fruiting body of *Fomitopsis betulina* growing on a fallen birch trunk. Photograph by Mariana Pelin Villani

Fig. 3 Selected objects from Ötzi's Copper Age equipment, illustrating the diversity of natural materials, tools and crafting techniques: a coiled cordage and lithic implements; b perforated stone disc with twisted hide strips, interpreted as part of a bird-carrying device; c flint dagger and woven sheath; d netted structure and fibrous bundle; e copper axe and blade; f leather strips and bound equipment components; g birch-polypore (*Fomitopsis betulina*) fragments attached to hide thongs; h stitched birch-bark container; i bone awl; j fragments of tinder fungus (*Fomes fomentarius*); k twisted fibre cords; and l coiled cordage and wrapped bundle. Together, these objects illustrate the range of materials and techniques involved in crafting, maintaining and transporting equipment, including fibre processing, knotting, binding, woodworking and the use of fungi. They provide material evidence of the practical knowledge and technical skills represented in Ötzi's equipment. Images: © South Tyrol Museum of Archaeology / Harald Wisthaler

Fig. 4 Modern reconstruction of objects associated with Ötzi's equipment at archeoParc Schnalstal. Two shaped pieces of birch polypore (*Fomitopsis betulina*) are threaded onto leather thongs and shown hanging from the waist belt, at left and centre, beside the perforated stone disc and leather thongs reconstructed as a bird-carrying tassel, at right. This arrangement represents the park's interpretive reconstruction rather than the documented archaeological position of the original objects. Photograph by Mariana Pelin Villani, 2025; reconstruction courtesy of archeoParc Schnalstal

Fig. 5 Razor strop made from *Fomitopsis betulina*, catalogue no. 30253, Economic Botany Collection, Royal Botanic Gardens, Kew. The object is historically associated with Helsingfors and Dr Nordenskiöld and probably dates to approximately 1857. Photograph by Mariana Pelin Villani, 2026; object courtesy of the Economic Botany Collection, Royal Botanic Gardens, Kew

Fig. 6 Specimen of *Fomitopsis betulina* collected from dead birch in Merionethshire, Wales, catalogue no. 38200, Economic Botany Collection, Royal Botanic Gardens, Kew. Its historical label records that the fungus was "used locally as a razor strop" and identifies Lady Bradford, O.B.E., as its donor in 1927. Photograph by Mariana Pelin Villani, 2026; object courtesy of the Economic Botany Collection, Royal Botanic Gardens, Kew

Fig. 7 Thin slice of birch polypore used for entomological labels and mounts, catalogue no. 30298, Economic Botany Collection, Royal Botanic Gardens, Kew. Accessioned in 1895 and catalogued under the historical name *Piptoporus betulinus*, the object carries a printed grid listing collecting localities and months and repeatedly names the entomologist J. J. Walker. The collection record identifies W. F. H. Blandford as its donor. Scale bar = 3 cm. Photograph by Mariana Pelin Villani, 2026; object courtesy of the Economic Botany Collection, Royal Botanic Gardens, Kew

Fig. 8 Exploratory flotation trial with a dried, shaped fragment of *Fomitopsis betulina* at archeoParc Schnalstal, South Tyrol, Italy. The fragment was threaded with lime-bast cord and placed in a pond to examine its buoyancy and integrity following immersion. Photograph and experiment by Mariana Pelin Villani, 2025

Fig. 9 Experimental investigation of *Fomitopsis betulina* as a possible fishing float in Marília, São Paulo, Brazil: a a dried, shaped fungal fragment attached to a fishing line beside a simple bamboo fishing rod; b the fungal fragment floating on the water surface during the fishing trial; and c a fish caught using the experimental arrangement, with the fungal float visible above it. This exploratory

602 trial evaluated the material feasibility of using birch polypore as a buoyant component of fishing
603 technology. Photographs and experiment by Mariana Pelin Villani
604