

RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

Food detection in medieval acoustic vessels: A case study from the early gothic churches in Myšeneč and Kovářov (South Bohemia)

Detekce zbytků potravin ve středověkých ozvučnicových nádobách:
Případová studie z raně gotických kostelů
v Myšenci a Kovářově (jižní Čechy)

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The subject of the article is two systems of acoustic vessels from the Church of St. Gall in Myšeneč, which is associated with the production of the so-called Zvíkov and Písek architectural workshop, and All Saints Church in Kovářov in South Bohemia. These vessels, built into the vault, were placed with their rim facing the interior of the presbytery and their bottom in the space of the attic at the same time as the construction of the vault and were probably intended to improve the acoustics of the interior of the presbytery. In the foreign synthesising literature, examples are described of custom-made vessels as well as secondarily used household vessels, i.e. those primarily intended for food storage. The paper aims to precisely determine the primary role of the vessels found in the two studied churches by detecting the hypothetical presence of food residues in them. Samples were taken from the inner surfaces of the vessels and their analysis showed a weak signal of casein (milk) in one case and a strong signal of gliadin (grain) in the other. The multiple potential functions of the vessels embedded in the vaults are discussed in the context of Czech examples and foreign research on acoustic vessels.

acoustic vessels – food residues – ELISA – medieval architecture – Myšeneč – Kovářov

Předmětem příspěvku jsou dva systémy ozvučnicových nádob, evidované v kostele sv. Havla v Myšenci (okr. Písek), spojovaného s produkcí tzv. zvíkovsko-písecké hutě, a kostele Věch svatých v Kovářově (okr. Písek). Tyto nádoby byly vezděny hrdlem do interiéru presbytáře a dnem do prostoru krovu současně s konstrukcí klenby a měly sloužit jako prostředek ke zlepšení akustiky presbytáře. V zahraniční syntetizující literatuře jsou doloženy jak příklady na míru zhotovených nádob, tak nádob druhotně užitých, tj. primárně určených pro uchovávání potravin. Ambicí předkládaného příspěvku bylo určit právě primární roli nádob, vezděných ve dvou studovaných kostelech, a to za pomoci detekce hypoteticky přítomných zbytků potravin. Z vybraných nádob byly odebrány vzorky z jejich vnitřních stěn, jejichž analýza prokázala v jednom případě slabý signál caseinu (mléko) a ve druhém silný signál gliadinu (obilí). V kontextu českých příkladů a zahraničních výzkumů akustických nádob je diskutováno více možných funkcí nádob zabudovaných do kleneb.

akustické nádoby – potravinové zbytky – ELISA – středověká architektura – Myšeneč – Kovářov

Dedicated to Therese Emanuelsson-Paulson and Jakob Lindblad.

Introduction

Built-in ceramic vessels preserved in the vaults of several medieval churches in the Czech Republic are generally accepted to be *acoustic vessels* (also known as *acoustic jars*, *resonant*

cavities), in other languages as *les vases acoustiques* (French), *Schalltöpfe* (German), *Ljudkrukor* (Swedish). Such vessels were likely intended for improving the acoustics of the interior, and thus they should be contemporary with the vault construction. Nevertheless, there is also evidence of vessels that were added later (*Desarnaulds – Loerincik 2001*, 67). In two local cases, vessels were found in a perimeter wall. The issue of acoustic vessels in medieval churches has been widely discussed (*Arns – Crawford 1995; Desarnaulds – Loerincik 2001; Brüel – Zaveri 2008; Palazzo-Bertholon – Valière 2012; Valière et al. 2013; Dorđević et al. 2017*) and has its traditional place in art historian, acoustic, and archaeology studies. Czech literature has dealt mostly with individual finds and records of embedded vessels. Only *Petr (1957)* and *Špaček (1963)* considered the wider European literature and critically presented all the hypotheses about the function of the vessels.

In the first part of the paper, the results of sampling for food detection in ceramic vessels will be presented using two case studies from the Church of Saint Gall in Myšeneč and All Saints Church in Kovářov (both in the Písek district, South Bohemia). The second part of the paper presents the known examples of ceramic vessel systems found in the Czech Republic. As local examples have not been included in foreign catalogues (see *Arns – Crawford 1995; Desarnaulds – Loerincik 2001; Palazzo-Bertholon – Valière 2012*), this paper aims to fill this gap and review them here as well. We will discuss existing theories based on an investigation of these vessels and examine a hypothesis suggested by older Czech and recent European research that some examples did not have to improve acoustics but could have been functional openings, serving as grommets or as air circulation vents.

Research question and its testimonial value

Through the interdisciplinary collaboration of an art historian and a molecular biologist, this paper aims to determine whether the artefacts were primarily used for food storage and embedding them in the vault structure was the second stage of their use, or if they were manufactured specifically for this purpose. Given the numerous foreign examples of household, storage or transport vessels being used as acoustic jars, we believe that this practice can also be assumed for certain Czech examples. In the absence of tangible attributes of household pottery, the detection of food residues seems to be the only available option to confirm or refute this hypothesis. It may well be that in some cases the vessels in which beverages for craftsmen had been stored on the building site were embedded in the vault. With slight exaggeration, we can mention in this context the paintings from Teruel Cathedral (Spain, 13th century), which roughly show us such a practice. Here, we can see several carpenters working the beams and another one in the middle, who distributes drinks to refresh them. This is exactly the scene we verify with our research – a vessel, intended for the storage of drink and analogous in shape to those we record, was hypothetically walled up as soon as it was finished and the stage of vaulting proceeded.

The shape and especially the appearance of the external decoration and the funnel or handle setting on the embedded vessel could indicate its secondary use. However, these attributes of household pottery do not necessarily imply that the vessels were actually used to store food – only that they were made for that purpose. It is, therefore, still necessary to distinguish between the primary function as fulfilled or unfulfilled. However, only in the absence of any of these visual clues can food residues be the clue to determining which

type of production was chosen. Establishing the primary function of the vessels is crucial for an interpretation of their incorporation into the building design and contributes to the understanding of medieval building practices in general.

The initial theory about the secondary use of ceramic vessels originated from the common (and not only medieval) practice of recycling. Such an example is the secondary use of timbers from previous roof trusses, older or broken architectural parts, reused in a new structure as a common building material replacing a regular brick or a stone block. Given the European analogies, where vessels of household production (whether used or not) have been embedded as acoustic vessels (*Yates 1897; Arns – Crawford 1995, 115; Desarnaulds – Loerincik 2001, 68; Tallon 2016, 269*), confirming or disproving the secondary use of the studied vessels would be another piece in the mosaic of contemporary knowledge about medieval building practices and construction procedures. The economic choice of recycling older vessels or ordering common household production speaks volumes about the thinking of the master builder and gives an idea of the time required to apply this specific technological solution. Simplified – using stock pieces had to be faster and cheaper than ordering custom production.

At the outset, it is important to note some of the postulates that will be discussed throughout the text. The embedding of the vessels itself could have been motivated by concerns about the acoustic quality of the building, as well as by an order or a desire to provide the building with an exclusive technological solution that a master builder had seen or heard about, for example. Such a situation was documented in the 1430s in Metz (*Petr 1957; Dragoun 1994*, for mentions from the 16th and 17th centuries, see *Desarnaulds – Loerincik 2001, 69*), when the prior recommended fitting the vault with pots to improve the acoustics; however, he had only seen such an arrangement once before and the local master builder, if not being familiar with such a procedure, had to rely not on experience but solely on intuition.

However, it should also be noted that the acoustic role of ceramic vessels is just an assumption that cannot be confirmed without reservation for all the examples known so far. In addition, the positive or negative signal of food residues does not preclude the use of the vessels as acoustic ones, but it says a lot about how the chosen technological solution was achieved and the modelling of the building project itself. It is also important to point out that even if the vessels could not improve the acoustics, it does not mean that they were not fitted for that purpose. Even though the role was intended to be acoustic, there are still several possibilities as to what kind of vessel to use for these purposes (*Fig. 1*).

Material and Methods

Selected churches

For the purpose of this study, churches in Myšelec and Kovářov were selected based on the similar time of their construction in the second half of the 13th century, geographical proximity of about 50 km, and the apparent contrast in the quality of the vessels and the quality of the buildings themselves. Four vessels were found in the vault of the Myšelec church (*Varhantík – Zavřel 1989*); in the Kovářov church, ten complete vessels and one imprint were recorded (*Sommer 1997*). Thus, in Myšelec, a relatively small number

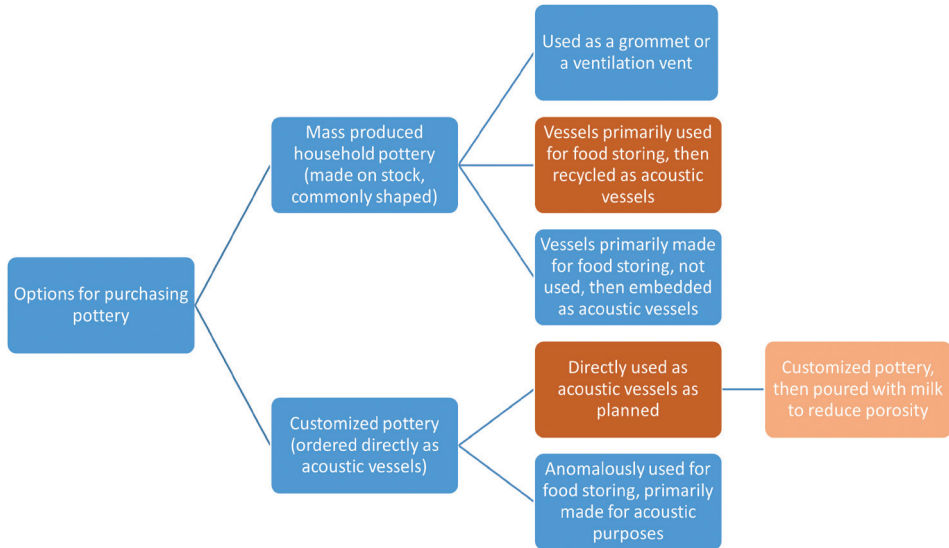


Fig. 1. Diagram indicating the possibilities for how vessels were used. Orange colour indicates the cases record in Myšelec and Kovářov.

of vessels were placed without any recognisable pattern (*Fig. 2*); in Kovářov, the vessels were arranged in a roughly regular way aligned to the longitudinal axis of the presbytery (*Fig. 3*).

These particular churches were also chosen because of the obvious contrast in the quality of the vessels used. In fact, the rustically made vault of the church in Kovářov was fitted with thin-walled vessels made from a single piece. On the contrary, in the exclusive realisation of the Myšelec church, associated with the activity of the well-known Zvíkov and Písek architectural workshop (see *Kuthan 1975*), massive vessels (atypically made of two parts) were used. The vessels in Kovářov thus appeared to be an example of mass production due to their obvious quality, while the vessels in Myšelec appeared to be a customised order.

Case study A – The Church of St. Gall in Myšelec

The Church of St. Gall in Myšelec is located in the very centre of the village, south of the remains of the Přemyslid royal residence. It is a single-nave church with a polygonal presbytery, a rectangular sacristy at its southern wall, and a western front tower (*Fig. 2*). The nave is aligned on a west-east axis, with the chancel and sacristy set back from the axis to the north. The western part of the rectangular unvaulted nave features a tribune divided into three bays with cross-rib vaulting. The sacristy, formerly considered to be the original church and now accepted as contemporary with the choir, is vaulted with a barrel vault.

The main structure is dated to the late 1250s or 1260s by previous research (*Kuthan 1994*), but it is necessary to assume a more complicated building history (*Adámek – Sommer 1998*). Based on its geographical proximity to Písek, historical property relations, the

Fig. 2. Church of St. Gall in Myšeneč, ground plan with vessels marked. Black – unsampled vessels; blue – vessels with a negative result; red – vessel positive result (according to *Varhaník – Zavřel 1989*, modified).

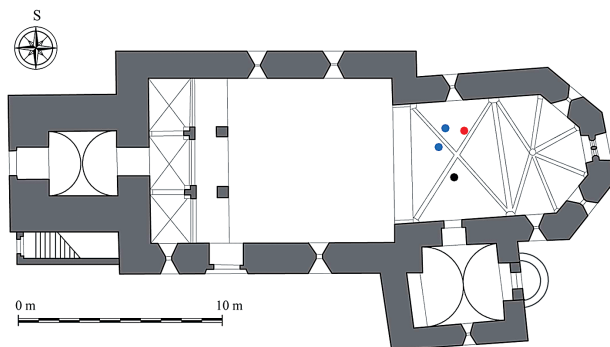
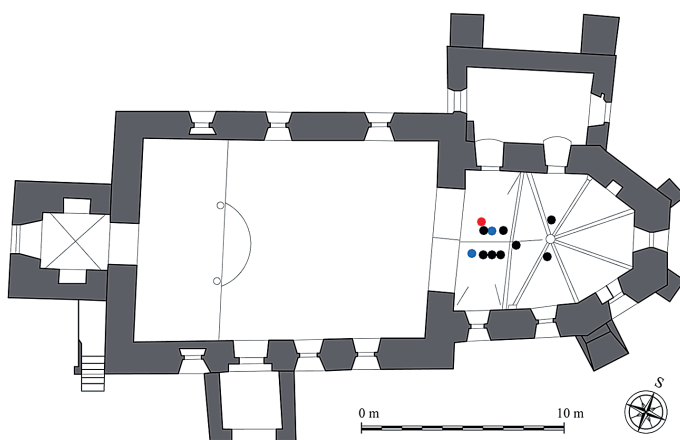


Fig. 3. All Saints Church in Kovářov, ground plan with vessels marked. Black – unsampled vessels; blue – vessels with a negative result; red – vessel positive result (according to *Sommer 1997*, modified).



existence of the royal residence nearby, and above all its morphological characteristics, the Myšeneč church was generally accepted as a product of the so-called Zvíkov and Písek architectural workshop. This idea was also supported by the appearance of a mason's mark on the southern portal. A similar mark was also recorded on the southeastern corner of the royal palace and in the northern wing of the courtyard arcade of Zvíkov Castle (*Kuthan 1975*).

In the case of Myšeneč, Jan Sommer pointed out the use of prefabricated architectural elements, which were implemented differently than for what they were initially modelled (*Adámek et al. 2001*). This note about the nature of the vault is crucial when the embedding of acoustic vessels is investigated. The contrast in the angle of the rib directions on the wall consoles and the vault ribs themselves shows that the consoles of the transition between the choir and the presbytery were designed for a space with a greater length. Thus, the console ribs spring at a sharper angle with the perimeter wall than the vault ribs, which were placed on the wall consoles in the last building phase after the original roof truss was built. The prefabrication of the unified architectural elements was further evidenced, again in connection with the Zvíkov and Písek architectural workshop, by the relationship between the wall consoles and the perimeter wall of the choir of St. Catherine's Church in Varvažov (*Sommer et al. 2003*), located 25 kilometres from Myšeneč. Altogether, they



Fig. 4. Church of St. Gall in Myšeneč, attic, brick vault of choir with embedded vessels (photo by F. Facincani).



Fig. 5. Church of St. Gall in Myšeneč, vessel no. 1 (photo by F. Facincani).

may indicate the production of uniformly shaped architectural elements manufactured for stock. Equally, it may simply be evidence that the consoles were made for this particular church, the ground plan of which was changed before the construction began. At the last moment, it may have been decided to shorten the length of the presbytery, as is expected in the Church of St. Dominic in Strunkovice nad Blanicí. However, this would have meant that the consoles would have had to be made before the foundations were laid.

Four ceramic vessels are preserved in the choir vault of the Church of St. Gall in Myšeneč (*Fig. 4*). Here, the vessels were placed asymmetrically near the top of the vault. They

Fig. 6. Church of St. Gall in Myšenec, vessel no. 3 (photo by F. Facincani).



Fig. 7. Church of St. Gall in Myšenec, detail of vessel junction (photo by F. Facincani).



were made of two pieces; the neck as an individual part was pressured into the body, jointed by an unknown rectangular tool. There are even two anomalous joining methods that are visible. Quite deep rectangular traces at the point of the junction of the neck and the body are prevailing (*Fig. 6; Fig. 7*, noticed by *Varhaník – Zavřel 1989*), but in one case the joint is smooth with just one wide curvilinearly-shaped depression (*Fig. 5*). Thus, we can see two different and not common types of junctions caused by the cooperation of two potters or an alternative technological method. Considering that the rectangular joints would have been possibly visible from the outside, their appearance could also signify that the vessels were not ordinary household pots.

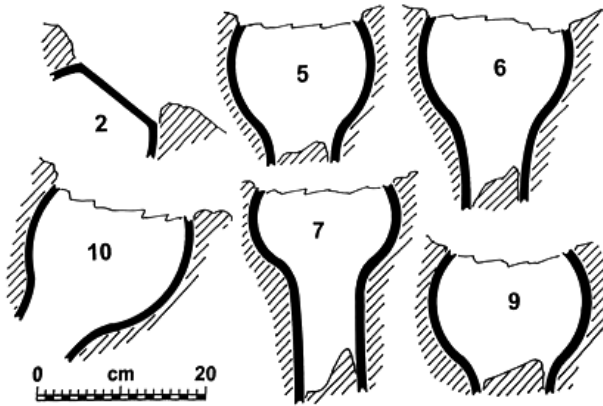


Fig. 8. All Saints Church in Kovářov, cross sections of vessels (according to Sommer 1997).

Case study B – All Saints Church in Kovářov

The oldest structures of All Saints Church of in Kovářov date back to the end of the 13th century (Sommer 1997). It is a single-nave church with a polygonal presbytery, sacristy, and a western front tower. The nave is not vaulted. The chancel is divided into a rectangular choir bay, with a pointed barrel vault, and a ribbed vault towards the polygon itself. The choir vault, described in detail by Sommer (1997), is very steep and placed on the more rustic architectural elements of basic and ordinary shapes. The top of the vault overhangs the crown of the perimeter wall of the choir.

The ceramic vessels set into the vault of All Saints Church in Kovářov were first published in a short study by Sommer (1997); quite rightly, he labelled them as a *system* of acoustic vessels, alluding to the fundamental difference in their number and arrangement in contrast to Myšelec. Compared to the vessels in Myšelec, the vessels in Kovářov are smaller in size, thin-walled, made of a single piece, and seem to be an example of a much higher quality pottery production than in Myšelec. In the set from Kovářov, vessels are similar in shape but vary in size and proportion (Fig. 8, see Adámek – Sommer 1997, 11).

Enzyme-linked immunosorbent analysis

There are several analytical approaches for the detection of food residues (lipids) in ceramics, but in this case, only the detection of proteins proceeded. This method of sampling was already described in detail by the co-author of this study (Pavelka 2020). Micro-samples were taken from three vessels for each site. The easily accessible inner surfaces of the vessels were chosen, where the highest concentration of food residues could also be expected. However, it has to be mentioned that the surface layers are almost always heavily contaminated – possible recent contaminations usually represent human keratin from the skin. Nevertheless, it can be easily excluded from the results. The sampling spot was first cleaned by fine grinding of the surface dirt with sandpaper. Using a scalpel, approximately 0.3–0.5 g of the sample (in an area of c. 2 cm²) was then collected in a plastic resealable tube as dust particles and each sample was assigned a unique registration number.

Methodologically and methodically, the presented research followed the previous works given for Czech environment, mainly by the studies of the co-author of this paper

(Pavelka – Vařeka 2008; Pavelka – Orna 2011; Pavelka et al. 2016; Kučera et al. 2018; Pavelka et al. 2020). A competitive enzyme-linked immunosorbent assay (ELISA) was used to analyse the collected samples. Tests were made using Veratox® for Gliadin R5 (see Lupo et al. 2013) and Veratox® for Casein (Neogen company). The manufacturer recommends a concentration for gliadin detection of 2 g of sample per 20 ml of extraction solution (60% ethanol), which for small amounts is 2 mg per 200 µl (and then diluted 1:50 with PBS solution before use), or 0.25 g per 10 ml of solution (2.5 ml PBS, then 7.5 ml 80% ethanol) corresponding to 2.5 mg per 100 µl (and dilute in PBS in a ratio of 1:12.5 before use). In the case of casein, it is recommended dissolving 5 g in 125 ml of PBS, which corresponds to 5 mg in 125 µl of PBS (Neogen company manufacturer's instructions). We used approximately 2 mg of the crushed and ground sample for the analyses, mixed with 150 µl of extraction buffer (allergen extraction buffer without additive, concentration 1:10), mixed vigorously using a vortex and then heated to 60 °C for one hour. After incubation, the sample was cooled to room temperature and centrifuged for 2 s at low speed (1000 RPM). Then, 100 µl of supernatant was used for the ELISA competitive test. In both cases, specific LG-biotin was added to the extract solution as the secondary antibody. Samples were compared with positive and negative controls. The intensity of the reaction is indicated by the intensity of the colour, which is then measured using a spectrophotometer. The samples were measured using an ELISA reader VERSAmax™ (Molecular Devices, San Jose, CA, USA) at 450 nm (see Pavelka et al. 2011; Kučera et al. 2018). For gliadin, the quantification range is 2.5–40 ppm. For casein, the quantification range is 2.5–15 ppm. Below 2.5 ppm, neither gliadin nor casein can be detected (Neogen company manufacturer's instructions). The tests were repeated twice for control.

It should be noted that the LC-MS/MS or MALDI-TOF methods are currently more preferred over antibody-based protein detection, especially for ancient proteins. In the past, antibodies to ancient proteins have not been very successful. However, this was because antibodies developed for recent native proteins were used, so they reacted poorly to degraded ancient proteins. Therefore, after a number of experiments, we use antibodies developed for degraded proteins. These were created for cooked foods, so some work well for ancient proteins from ceramics. Mass spectrometry and antibody detection are complementary and often confirm each other (see Pavelka et al. 2016; Kučera et al. 2018; Pavelka et al. 2020). Mass spectrometry captures a wide range of proteins, but identification of, e.g. milk to species is so far handled less well or not at all. Because the method is well validated using the antibodies detected, it was used in this study. For larger studies, we plan to use both methods simultaneously.

Results

From the six tested samples, only two were positive, one for each site (*Tab. 1; Fig. 2 and 3*). In the case of Kovářov, we managed to detect a relatively strong signal for gliadin, which points to the presence of grain in one of the vessels. In Myšenec, casein residues were found again in only one vessel, proving the presence of mammalian milk (we did not attempt to determine the species).

It should be emphasised that the samples from both sites were taken from an area of the vessel body close to the bottom. The specific attic temperature conditions may have caused

	Sample number	Casein (milk)	Gliadin (grain)
Myšenec <i>Church of St. Gall</i>	1	0	0
	2	+	0
	3	0	0
Kovářov <i>All Saints Church</i>	1	0	++
	2	0	0
	3	0	0

Tab. 1. Results of immunological analysis of samples from medieval acoustic vessels. 0 – negative result; ++ – positive result; + – weakly positive result.

the absence of other positive results. High temperatures in the summer in the attic do not favour the preservation of proteins, so testing was only performed when there was a chance of obtaining results. For further testing, it would be appropriate to try to find lipids in the ceramics and analyse their origin.

The way the body and the neck of the vessels were connected in Myšenec suggests that they were not made for sale or had any aesthetic appeal. Indeed, as earlier research suggested (*Varhaník – Zavřel 1989*), they seem to have been made specifically for construction purposes as customised pottery. Although the circumstances are somewhat unclear, it seems they were installed without a deeper knowledge of using such a system. As one of the examined vessels provided a weak casein signal, at least one of them was occasionally used for storage or at least came in intense contact with mammalian milk. It is, therefore, a question as to whether these vessels were custom-made and unexpectedly used for storing milk during construction or household vessels of questionable quality. The atypical method applied during their manufacturing indicates custom-made production, which at first glance is inconsistent with the weak traces of milk. A third possibility to explain this deadlock situation is a technological process whereby the porous ceramic was filled with milk to reduce its porosity (*Čiperová 2015, 35; Čiperová et al. 2015; Hlásek – Pavelka 2016*).

In Kovářov, traces of gliadin were found in one of the three sampled vessels (out of a total of eleven). It can be assumed that this vessel was used for storing an unspecified liquid grain product. Given the vessel's shape, it can be cautiously assumed that it was a beverage, likely an ale or some sort of grain brew. The technological nature and various sizes of these vessels combined with the presence of gliadin in one of them seem to be the convincing arguments for a broadly documented working process, whereby the Kovářov vessels were bought ready-made, primarily used, and then recycled. Even vessels used on the building site might be embedded in the vault.

Discussion

In this section, we discuss two topics. In the first part we focus on the custom of recycling of household pottery, proven above, and present the foreign context for it. In the second part, we relativise the established assumption that ceramic vessels served without exception as resonators, and present clues that may speak in favour of vessels perforated immediately after their embedding to serve as ventilation vents or grommets.

Site	Patrocinium	Placement	Number	Chronology
Červená nad Vltavou	St. Bartholomew	choir vault	-	13th century
Dobřš	Annunciation of the Virgin Mary	choir vault	1	14th century
Cheb	Minorite Monastery Church	choir vault	8	13th century
Jílové u Prahy	St. Adalbert	choir vault	3	14th century
Kovářov	All Saints	choir vault	11	13th century
Myšenec	St. Gall	choir vault	4	13th century
Ostrov u Davle	monastery church	perimeter wall	1	12th century
Pošná	St. Bartholomew	choir vault	8	13th century
Prague	Rotunda of the Holy Cross	perimeter wall	2	12th century
Rychnov nad Kněžnou	St. Gall	choir vault	20	14th century
Vitice	St. Simon and Jude	choir vault	-	14th century
Vrchotovy Janovice	St. Martin	choir vault	4	14th century

Tab. 2. Alphabetical list of acoustic vessels recorded in the Czech Republic until 2024.

Previous local research on acoustic vessels in the Czech Republic

A pair of ceramic vessels built into the perimeter wall of the nave and apse of the Rotunda of the Holy Cross in Prague was already recorded by J. E. Vocel in 1865 (see *Dragoun 1994*). A study by *Petr (1957)* on the vessels in the vault of the square presbytery of the Church of St. Bartholomew in Pošná can be considered as the beginning of systematic research, which was followed by the essays on the Ostrov Monastery (*Špaček 1963*), the Church of St. Gall in Myšenec (*Varhaník – Zavřel 1989*), the Church of the Annunciation to the Virgin Mary in Dobřš (*Fröhlich 1990*), the Rotunda of the Holy Cross in Prague (*Dragoun 1994*), the Church of St. Adalbert in Jílové u Prahy (*Jesenský 1995*), the church of the Minorite monastery in Cheb (*Varhaník 1997*), and All Saints Church in Kovářov (*Sommer 1997*). Along with these, vessels of this type were documented in Vrchotovy Janovice, and, according to historical photo documentation, in the vault of the choir of the Church of St. Bartholomew in Červená nad Vltavou (*Varhaník 1997; 1998*). Recently, ceramic vessels embedded in the vault were documented in the Church of St. Gall in Rychnov nad Kněžnou (*Prix et al. 2020; Bláha – Slavík 2022*) and most recently in the Church of Saints Simon and Jude in Vitice, identified by Jan Kypta and Jan Veselý (pers. comm.). Above all, a brief summary of local research and an exemplary documentation of vessels from Rychnov nad Kněžnou have been presented by *Bláha and Slavík (2022)*. The nature of the ceramic vessels found during the archaeological excavation in Kladruby Monastery is still unclear, although their context may suggest that they are acoustic jars (*Nováček et al. 2010, 100*). To date we are aware of 12 examples of embedded ceramic vessels, not including a questionable example from Kladruby (*Tab. 2*).

Almost in all cases, the vessels had been partially destroyed. In the Ostrov Monastery, the bottomless vessel was excavated. On the other hand, there are two vessels with a bottom preserved, posted beneath the vault surface in Kovářov. In the Rotunda of the Holy Cross, the mass of a perimeter wall protects the vessels. A few vessels are fully preserved in Rychnov and Kněžnou. Based on the paper by *Petr (1957)*, we can assume that vessels were still fully preserved in the vault of the Church of St. Bartholomew in Pošná in 1957.

Unfortunately, in the 1990s, the vault was almost completely covered with concrete. We did not find any photographic or written documentation from before this inappropriate intervention, which destroyed possibly the most intact and fully preserved vessels in the Czech Republic.

The earliest local systematic research on ceramic vessels in churches already proposed three basic functions for them primarily based on foreign examples (*Petr 1957; Špaček 1963*). According to the collected opinions, the vessels could either lighten the vault, protect the interior from moisture, or improve the interior's acoustics (also *Desarnaulds – Loerincik 2001, 69*).

Concerning the first function, it should be mentioned that using ceramic vessels as the sole or filling component for vault construction is a well-known technological practice (see *Lancaster 2009; Caroscio 2010; Volfová 2018*), but it differs significantly from the way these examples were used in the investigated buildings and therefore is irrelevant to this paper. As for the acoustic and ventilation benefits of the pots, it is critical to point out that they could have served as resonators only if they were not blinded (plastered) from the interior and their bottoms were intact on the attic side. Conversely, they could improve air circulation without plastering on the interior wall but with opened bottoms towards the attic space, i.e. in a modified form. And while the ventilation and acoustic interpretations need not be mutually exclusive, the Czech research community has widely accepted the latter option and identified ceramic vessels as acoustic jars. Local scholars have expressed various opinions on the origins of these vessels. Z. Dragoun assumed that in the case of the examples dated from the 13th century they were made as custom-made pottery, while for the Rotunda of the Holy Cross from the 12th century, he posited the secondary use of vessels (*Dragoun 1994, 118*). Thus, if we accept that their primary use was intended for acoustic purposes, it could have been motivated by a concern that the acoustic qualities of the building (still under construction) would be inadequate or a master builder wanted to add and present some trend they had heard about. *Špaček (1963, 139–140)* commented on the use of either recycled or custom-made vessels. *Jesenský (1995, 53–54)* suggested, in connection with the research on the Church of St. Adalbert in Jílové u Prahy, that the vessels were installed in response to the non-axial junction of the nave and presbytery, which could have had a negative effect on the acoustics. We also know this kind of uneven junction between the nave and presbytery from both Myšelec and Kovářov. In the case of Myšelec, the rustic manner of processing the vessels, the local origin of the temper and the variable thickness of the walls point towards the interpretation that the pots were neither the product of a specialised workshop nor an import (*Varhaník – Zavřel 1989*) and were made from local material. In contrast, J. Sommer interpreted the vessels from All Saints Church in Kovářov as special, directly commissioned customised orders. Also, L. Čapek commented on the intention of the secondary use of household pottery and its recycling, and he included these examples under the term *cultural remains* (*Čapek 2010, 21*), mentioning both the vaults of pottery kilns (see *Volfová 2018*) and acoustic vessels.

Food storage as the primary function of acoustic vessels in Europe

According to R. G. Arns and B. E. Crawford, in 41 out of 52 cases of vessels that appear to be acoustic ‘...utilitarian pottery produced in the area at the time of the construction of the structure...’ was used and the rest ‘...made for the specific purpose; either the shape

or details of construction make it clear that they [vessels] were made for installation in the church walls.’ (*Arns – Crawford 1995*, 114). Gordon Hills mentioned four vases built into the 15th-century wall of a church in East Harling, Norfolk (see *Yates 1897* and *Arns – Crawford 1995*). These were identified as burial urns from 4th or 5th century AD, meaning that the vessels had been used secondarily. Other acoustic vessels were found in Mancroft (1850) and Mountergate (1860), both in Norwich, and were described by G. C. Yates in 1897 (*Yates 1897*). The construction solution is the same in principle for both, in Mancroft doubled in plan. Here, the vessels were found without any supplements added. On the other hand, the vessels from Mountergate were furnished with handles. This does not mean these vessels were actually used as food containers, but they were initially made for that purpose. According to P. Carvalho and colleagues, ‘René Floriot noted that the pottery used in the churches was common and of all types, and did not correspond to any specific production intended for this use.’ The authors also pointed out that ‘the vessels are ceramics for domestic use’ and ‘the two examples studied show traces of use in a fire’ (*Carvalho et al. 2009*, 10, translated; see illustration n. 2 of a *vase d’église de Fiquefleur-Equainville* with a handle, see also *Desarnaulds – Loerincik 2001*, 68). Another built-in vase with a spout and a handle was already mentioned by Floriot in Villeneuve les Avignon (*Floriot 1964*, cited by *Tallon 2016*) and recalled by Andrew Tallon in his study about the 19th century *caveau phonocamptique* of Noyon Cathedral (*Tallon 2016*, fig. 12). As in the previous cases, Tallon mentioned that ‘as in the chamber at Noyon, common household pots, often with pouring spouts, were standard’ (*Tallon 2016*, 269). In summary, we can say that both customised and household vessels were commonly used. In the latter case, we can distinguish whether they were directly used before their secondary use or if they were just made for storage purposes but never served as such. Food remnants could be another clue of their household use if the tangible attributes are not visible were never there actually there (or if the shape of the vessel itself offers no clues).

Irregular placement and the number of vessels as possible indicators of secondary use

In Vrchotovy Janovice, we can see three vessels at the very top of the choir vault and one at the top of a vault of a polygonal presbytery. The latter was squeezed between the rib and the ridge rib, near the keystone. Aside from the fact that this particular placement is random, we can distinguish similar but still variable sizes of the vessels that were used. This kind of irregular placement of ceramic vessels, including in Myšenec and Vrchotovy Janovice, leads us to the question: why doesn’t the number of vessels match the number of webs in the vault? It may appear reasonable if the number of vessels installed was limited by how many were on hand at the building site for storing purposes. In that case, the vessels would not have been ordered according to the number of planned vaults as a custom order but were installed in the number that was available. This would perhaps explain why three of the four were put into the choir area and one into the presbytery in Vrchotovy Janovice. The number of available household vessels could directly determine all of these awkward and irregular placements. At least we can say that financial limits were not the reason for installing three vessels instead of four.

Compared to foreign examples, the number of vessels in the Czech Republic is average or below average, which may be due, among other things, to the size of the built spaces.



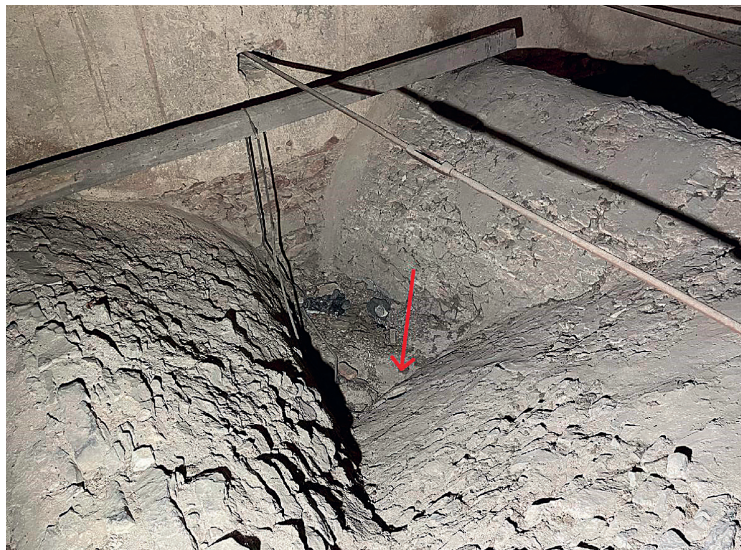
Fig. 9. Church of Saint Mary in Kamień Pomorski, vault (photo by M. Kubínová).

For example, the survey by *Desarnaulds and Loerincik (2001)* recorded at least five vessels (Villette), with an average of 20. According to *Arns and Crawford (1995, 114)*, the minimum was three, the maximum 113, with an average of 22. We also know of lower numbers of vessels preserved in Serbia (*Đorđević et al. 2017, 112–117*). For the Czech examples, the number varies and not always in direct proportion to the size of the vaults or the presbytery. In the case of vessels embedded in vaults, their number rarely exceeded 10. Of the sites where the original number could be reconstructed,¹ the minimum was one (Dobrš), the maximum 20 (Rychnov nad Kněžnou), with an average of six. However, it must be pointed out that such statistics are in a way irrelevant if we consider that we can see just an incomplete system and some of the recorded systems served to improve acoustics, but others only as air circulation systems or grommets for hanging chandeliers, etc.

On the island of Gotland, for example, only three vessels were recorded by *Lagerlöf and Svahnström (1991)* in Akeböck Church, set in a row at the top of the barrel choir vault. However, the similarly designed church at Ganthem has a single vessel, as does the younger church at Stenkumla. Eleven vessels were also described in Dalby Church, Skåne. *Brycki (2018)* analysed the reverberation time and compared the acoustic conditions of Dalby Church in the 15th century and today. As a result, he summarised that the number of vessels is too small to improve the acoustics. According to *Brycki*, we should consider another possible function of the so-called acoustic vessels. As an alternative, he proposes the use of holes for anchoring scaffolding or structures related to the construction of the vault (see also *Sommer 1998, 83*). For example, the regular pattern of rectangular holes in

¹ The authors are not aware of the number of vessels in Červená nad Vltavou and Vitice. In the former case, photographic documentation is insufficient, thus we cannot specify the exact number of vessels. *Varhantk (1998, 299)* compared this situation with Pošná example, so we can only hypothetically assume that there were 8 vessels in Červená nad Vltavou. However, other local examples teach us that a regular system may not have been applied.

Fig. 10. Church of Saint Adalbert in Jílové u Prahy, vault of choir with a vessel marked by an arrow (photo by F. Facincani).



the vault webs of St. Mary's Chapel in St. Nicholas Church in Stockholm (Storkyrkan) is interpreted in the same way. We also know a similar situation from St. Mary's Cathedral in Kamień Pomorski (Fig. 9). Here, rectangular holes set in the same position are emphasised by painted faces with open mouths and a yelling expression. This decoration itself may indicate an awareness of the acoustic role of the holes. However, the setting of the ceramic vessels in this church precludes their rectangular shape.

An interesting example is an interpretation of seven, also rectangular, holes in a vault of St. Catherine's Rotunda in Znojmo (11th century). They were interpreted as functional openings used for fixing the wooden structure during lantern construction (Konečný 2005, 32). However, Sommer (1998, 81; see also Konečný 2005, 35) pointed out that their plastering had a bad effect on the interior mural paintings, due to the increasing humidity. These cases illustrate very well the understandable lack of clarity in any interpretation.

Ceramic vessels as ventilation vents – Jílové u Prahy as a key case?

Three ceramic vessels were found in the choir vault of the Church of St. Adalbert in Jílové u Prahy and published by Vít Jesenský in 1995. As previous research suggested, their bottoms were probably destroyed during some later reconstruction of the roof truss (Jesenský 1995, 52). However, the bottoms of the vessels are broken off quite regularly and their rims are evenly aligned with the surface of the vault. No remains of broken sherds were preserved in the rubble or inside the vessels. This situation raises the question of whether it is really the result of the vessels being accidentally stepped through during the more recent reconstruction. At the same time, the vaults in Jílové are extremely steep (Fig. 10) and it is very difficult to get directly to the vessels, not to mention how difficult it would be to step through such a vessel and how likely it was that they would be destroyed all at once. These indications suggest that the vessels were not broken accidentally, but on purpose and as soon as the mortar set. On the other hand, Vít Jesenský (1995) considers the

secondary breakage to be a misunderstanding of the acoustic role and an attempt to use the newly created openings as ventilation vents. Both options are naturally possible. When we accept the ventilation function, it is also important to record empty vault webs, i.e. missing vessels in an otherwise regular pattern. The course of original service footbridges above the vault and in the attic should be considered. In Jílové u Prahy and in Cheb, the vessels were installed in all vault webs except those over which the service footbridges lead. It is probable that such movement structures were also placed here in the Middle Ages. Omitting the vessel under the footbridge would then have prevented dirt from falling into the interior of the church.

Such a ventilation purpose was already suggested by several scholars such as Jacopo Morelli (*Morelli 1800*, 40–41, see also *Petr 1957*) and Werner Stöckli (see *Desarnaulds – Loerincik 2001*, 69) in the case of embedded ceramic vessels. Stöckli rightly pointed out that a ventilation vent makes sense in a lower part of the vault. The ideal example he was calling for is the situation in Pošná; however, here the vessels were not perforated, which is necessary for a vent.

Whether or not, we must always keep in mind the difference between the ideal situation represented either by the number or the distribution of vessels, and their actual impact. As indicated above, the fact that the vessels could not improve the acoustics does not mean that they were not installed for that purpose. The question of their placement and acoustic or ventilation purposes should be viewed in the same way. It is necessary to study their number, the preservation of the bottom, and their location or position in relation to the design of the vault.

Conclusion

With the present state of knowledge, the so-called acoustic vessels documented in the Czech Republic were all recorded inside sacred architecture. The question is whether this is a consequence of their function, which could have been directly related to the liturgical role of sacred spaces, or whether it is because medieval sacred architecture is generally much better preserved than profane buildings. In the case of the two oldest Czech examples (Ostrov Monastery; Rotunda of the Holy Cross, Prague), vessels were built into the perimeter wall, not the vault. The remaining examples are recorded in the vaults of presbyteries, and thus either in the vault of a square choir, in a polygonal presbytery itself, or both. In the examples observed, it is possible to see a completely regular arrangement, as well as a wholly irregular or incomplete one with an attempt to maintain regularity. The vast majority of the vessels were made as a single piece on a potter's wheel, but in the case of Myšenec, there are two atypical connections of the body and neck. In most vessels, the bulbous modelling of their bodies is also evident; only in the case of Pošná were the vessels of a straight pipe-like cross-section. Most of the vessels were originally or secondarily pierced at the bottom when viewed from the attic and secondarily blinded when viewed from the interior (except Pošná, for example). Based on the earlier evidence (Pošná, Kovářov, Rychnov nad Kněžnou), it must be assumed that in some cases, the vessels were intended to remain complete when viewed from the attic and open when viewed from the interior.

The random placement of the vessels leads to the logical presumption that the master builder was unfamiliar with this practice or did not know it from experience. In the words

of N. Kanev, it seems that the use of acoustic vessels was, in many cases, the ‘result of orally transmitted tradition, without any real knowledge of their function’ (Kanev 2020, 400). It is thus possible to imagine that the master builder had only heard of such a phenomenon and wanted or was required to enrich the vault of the presbytery in this way.

Recording food residues or visible attributes such as handles, funnels, or exterior decoration may be evidence of recycling. However, no such surviving attributes have been identified yet in the Czech Republic. Another indicator of secondary use may also be the number of vessels used, especially when confronted with the number of vault webs within the built space. If only three vessels were fitted into a square presbytery of four webs, this speaks more to the fact that only three were available than to financial limits or other factors. In other words, the builders used what they had on hand. It is important to note that the size of the vessel had to correspond roughly to the thickness of the planned vault. This circumstance may also have triggered the need for custom production (Myšenec, perhaps). However, the varying heights of the vessels used (Pošná, Vrchotovy Janovice, Kovářov, etc.) are also another possible indicator of the secondary use of household pottery. Although the bottoms of most vessels are not preserved, their variable sizes are indicated not only by the orifice diameter but also by the size of their bodies and the varying use of mortar beds for their fixation and covering on the reverse of the vault on one building (see *Desarnaulds – Loerincik 2001*, 68, mentioning examples found in Villette; also evident in Vrchotovy Janovice). The use of acoustic vessels may not have had the same purpose in each of the studied buildings. Likewise, the role of each of the churches must be reflected. Thus, it is necessary to distinguish between using acoustic vessels in the presbytery of a mendicant monastic church and a regional church. Similarly, it must be assumed that some acoustic systems were planned from the beginning of the construction, while others were an *ad hoc* response to the specific circumstances of a particular building or an external impulse (building team change for example) – or were not acoustic systems at all.

Previous research naturally accepted all local examples as systems of acoustic vessels and in some cases, there is probably no reason to doubt this. Scholars also assumed that the bottoms of embedded vessels had originally been visible above the vault and were destroyed during some later or even recent reconstruction of the roof truss. Nevertheless, we can suggest that some of the ceramic vessels were broken immediately after embedding and served as a regular framing of the vent to circulate air (Jílové u Prahy, perhaps). The walling of the ceramic vessel was easier than the walling of a wooden log (later pulled out) or leaving the opening rough and irregular, defined only by the rubble masonry. Thus, the vessel would serve as a supporting construction, ensuring the regular shape of the opening and simplifying the mason’s work.

Traces of food remnants were found at both analysed sites. A weak signal for unspecified milk was detected in one of the vessels from Myšenec, and a strong signal for grain was detected in Kovářov. The significance of these results increases if compared with the technological design of the vessels. It has already been suggested (*Varhaník – Zavřel 1989*) that the Myšenec vessels were likely custom-made, which is matched by their very rustic design, all the more striking when compared to the high quality of the building itself. The traces of milk can perhaps be explained as evidence of a process whereby the vessels were filled with milk to prevent leakage, i.e. a procedure the potter would have been familiar with and which was applied on all his production. In contrast, the quality of the vessels from Kovářov is much higher, which contrasts with the poor quality of the church vault.

This was already an indication that the vessels may have been recycled household pottery (in contrast, see *Sommer 1997*). This is confirmed for at least one vessel by the evidence of a strong grain signal, i.e. it can be assumed that this vessel was first used to store a grain-based beverage. The presented research expands the possibilities for a broader study of this technological practice and at the same time demonstrates that this phenomenon cannot be viewed in a generalising way.

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