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Reviewed Article:

Beeswax an Addition to the Production of European Stone Age Adhesives

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Beeswax is a frequently mentioned binder additive in the literature. Unfortunately, it is not so durable as to be well preserved in archaeological records, although there are faint exceptions. Because of its strengthening capabilities, which is believed to be its role, this research set out to carry out an experiment to verify the effects of adding it to the adhesives potentially used in the European Stone Age. The study used pine resin and its various compositions with beeswax and frequently used charcoal. The binders obtained were then compared with birch

tar, which is considered to be one of the best adhesives in prehistory. Arrow ballistics were used to verify the effectiveness of beeswax addition, which shows that this addition has a high-quality effect on the natural binders.

> Beeswax is one of the most commonly mentioned additives for prehistoric adhesives. The present experiment set out to empirically test whether it actually affects the physical properties of natural binders.

Introduction

The formation of adhesives, especially composite ones, is recognised as one of the most important pieces of evidence for complex cognitive thinking in prehistoric humans (Wynn, 2009; Wadley, 2010; Kozowyk, Langejans and Poulis, 2016). Among the potential glues of the European Stone Age are birch bark tar and pitch, pinewood tar and pitch, pine resin, hide glue, and even Blue Bell glue (e.g. Osipowicz, 2005; Mazza, et al., 2006; Pfeifer and Claußen, 2015; Kaňáková, 2020). In the case of resins, which appear to be the most natural and the easiest to obtain, various additives were probably used to improve them. Amongst archaeologists, admixtures of charcoal, ash, animal fat, or finally, beeswax are commonly mentioned (e.g. Clark, Phillips and Staley, 1974; Rots, 2008). The most interesting of the additions is the last one mentioned. Unfortunately, unlike the others (e.g. Gibson, Wadley and Williamson, 2004), it is not preserved in the archaeological records and needs a special chemical analysis to be undertaken (Regert, 2004; Rots, 2008; Kozowyk, Langejans and Poulis, 2016). Nevertheless, it is believed that it was used, and its inclusion had a positive effect on the other adhesives (e.g. Rots, 2008). The aim of this experiment was to verify the effect of the beeswax addition to a natural resin.

Methods

To examine the properties of beeswax in natural resin, pine resin was used. This was done by heating it on a hearth and after obtaining approximately 6-7 g of the substance it was enriched then by gradual addition of small lumps of beeswax (about 2-3 g). This verified empirically not only its stickiness but also its setting time. In order to verify the properties of the adhesive, pine resin with the addition of charcoal and the same variant with the addition of beeswax were also prepared. All the adhesives obtained were then compared to an adhesive obtained from natural resin without additives and birch tar. A total of 5 adhesives were used: 1) pine resin; 2) pine resin with beeswax; 3) pine resin with charcoal; 4) pine resin with charcoal and beeswax; 5) birch tar. Four of the adhesives were made *ad hoc*, while the fifth was prepared in advance (Lis and Wasilczyk, 2021).

Prehistoric arrow ballistics was used as a research method. For this purpose, five arrows were prepared from calla (*Viburnum op.*) and dogwood (*Cornus mas*), which were feathered and fitted with flint arrowheads. The production process followed the scheme described by Sadło

(2021). The feathers of wild birds were used for the flights, while the arrowheads were replicas of Late Neolithic specimens from Central Europe. The premise of the experiment was to use the arrows and observe changes in the adhesive properties.

Two bows with different tensile strengths were used for shooting. In the case of the weaker bow, a replica of the Neolithic Bolkow bow from Poland was used (string strength 17 kg), previously made on commission. In the case of the stronger bow, a replica of a medieval bow was used (string strength 25 kg). The use of two different bows was dictated by the desire to operate the arrow efficiently. All experiments were conducted in May 2021 at the experimental archaeology centre at Grodzisko Żmijowiska.

Results

The experiment was divided into two stages: 1) adhesive production; 2) arrow ballistics. As a result of the first stage implementation, four adhesives were prepared. The production process and observations resulting from their behaviour are described below. The fifth, birch tar, although prepared earlier, will be briefly discussed last.

Stage I. Adhesive production

Pine resin

It was obtained by harvesting it from the bark of pine trees (See Figure 1). In its natural form, it was heated on the hearth at a temperature of approximately 550 °C. It proved to be easily affected by heat, melting very fast. After liquification, it was purified of organic inclusions (See Figure 2). After purification, it was allowed to sit for 10 minutes. In a sticky-liquid form, it was applied to the arrow, and then the arrowhead was attached.

Physical observations: When freshly melted, it is slightly more elastic, changing colour from yellow to orange/red at maximum melting. It sets quickly, especially at low temperatures, a little slower at higher temperatures. It has a translucent orange colour when dry and is very crumbly – it is not possible to correct the position of the arrowhead.

Pine resin and beeswax

The pine resin obtained by harvesting it from the bark of pine trees was then heated and cleaned of natural organic intrusions. Then, small lumps of beeswax (about 2-3 g) were added to the molten resin. This was stopped at 8 g when the consistency of the liquid was more fluid, and specific fatty meshes began to form. After mixing the resin and beeswax, the glue was left to set. After 30 minutes, it was still watery. Although the process was very slow, after about 50 minutes, the sticky-liquid effect was achieved (See Figure 3). The adhesive was then applied to the arrow shaft, and the arrowhead was attached.

Physical observations: Although the setting process takes a very long time, the adhesive has great properties. It becomes a strong amber-coloured bond - it gets its matt colour from the beeswax. It is very sticky. You can fix the arrowhead and do the correction because even after fixing, the glue hardens slowly.

Pine resin and charcoal

The pine resin obtained by harvesting it from the bark of pine trees was then heated and cleaned of natural organic intrusions. Then, the small portions (about 1 g) of the crushed charcoal were added (See Figure 4). After mixing, it was allowed to set for 10 minutes. In sticky-liquid form, it was applied to the arrow, and then the arrowhead was attached.

Physical observations: It sets quickly, especially at low temperatures, a little slower at higher temperatures. It has an intense black colour and is very crumbly – due to rapid hardening process it was not possible to correct the position of the arrowhead.

Pine resin, charcoal and beeswax

The pine resin was obtained by harvesting it from the bark of pine trees and was then heated and cleaned of natural organic intrusions. Then, small portions of crushed charcoal (about 1 g) and small lumps of beeswax (about 2-3 g) were added – the latter was stopped at 8 g when the consistency of the liquid obtained was fluid and specific fatty meshes began to form. The liquid was left to set. After about 30 minutes, it obtained a sticky-liquid form (See Figure 5). The adhesive was then applied to the arrow shaft, and the arrowhead was attached.

Physical observations: The substance obtained is matt and greasy. On solidifying, it becomes very sticky. After setting it is very strong, however, the slow hardening time made it possible to correct the position of the arrowhead.

Birch tar

The birch tar was extracted during the Experimental Archaeology Workshop conducted in 2013 at the experimental archaeology centre in Grodzisko Żmijowiska. It was obtained by the earth pit method (Lis and Wasilczyk, 2021, pp.136-139). The obtained substance was then stored at room temperature in a glass vessel. It was used in May 2021, and the birch tar was heated on the stone at a hearth (See Figure 6). It was then applied to the arrow shaft in the form of a sticky liquid, and an arrowhead was applied.

Physical observations: The birch tar, after heating, has a very good adhesive strength. It is an elastic substance with matt black colour and excellent tack. Unfortunately, the tar has shown very poor setting properties. Even after drying all night, it was still sticky, and the attached arrowhead was moving. At higher daily temperatures (above c.a. 25 °C) and intense sunshine, it would fall out of the saddle on its own. Since tar is considered to be a binder with excellent properties, it must be thought that the reason for this situation was probably the age of the tar. It may have lost its properties during storage.

Stage II. Arrows ballistics

One arrow was made for each adhesive according to the procedure described by Sadło (2021). The arrows were made from calla and dogwood (See Figure 7). They weighed approximately 24-30g. A replica of a Late Neolithic arrowhead was attached to each arrow. A different adhesive was used for each arrow (See Figure 8). Then it was left to set. The arrows with the four pine-based glues were completely ready to shoot after about 1.5 hours. In the case of the birch tar, it was decided to wait until the next day. Unfortunately, it did not achieve the expected result - it was still quite sticky, but the arrowhead was immobile, so this arrow was used for further testing.

The prepared arrows were shot in 8 rounds. For the first five rounds, a replica of a Neolithic Bolkow type bow was used; for the final three other rounds, a replica of a medieval-type bow was used. Shots were fired at a straw target on a wooden stand from a distance of 20 m.

The results of the ballistic experiment showed that the most durable adhesive was a mixture of pine resin and beeswax (see Table 1). It survived intact in all eight trials. The second glue in order of survival was a mixture of pine resin with beeswax and charcoal. This survived all the tests with the lighter bow. With a heavier bow, it failed – the arrowhead fell off along with a large part of the binder (See Figure 9). The least durable adhesives were pine resin and tar. In the first case, the hardness of the glue combined with the force of the impact caused the binder to crumble off and the arrowhead to fall off from the arrow shaft. In the second case, the softness of the material was such that when it hit the target, the arrowhead on the arrow shifted, although it did not fall out. However, this showed that the material was not suitable for experimentation. Therefore, further shooting attempts were abandoned. The adhesive that qualifies as neither the most nor the least durable is a mixture of pine resin and charcoal. It withstood two attempts using a weaker bow, only failing at the third attempt – the arrowhead fell off the arrow. This shows that it is a pretty durable binder but susceptible to arrow fatigue or even a target with greater hardness. It can therefore be concluded that, with the different adhesives used, those admixed with beeswax were the most durable (See Figure 10).

Adhesive	The Bolkow type bow					The medieval type bow		
	Round I	Round II	Round III	Round IV	Round V	Round VI	Round VII	Round VIII
Pine resin	X	–	–	–	–	–	–	–
Pine resin and beeswax	O	O	O	O	O	O	O	O
Pine resin and charcoal	O	O	X	–	–	–	–	–

Pine resin, charcoal and beeswax	O	O	O	O	O	X	–	–
Birch tar	X	–	–	–	–	–	–	–

TAB. 1. RESULTS OF THE BALLISTICS EXPERIMENT. X – THE ADHESIVE DEMONSTRATED NEGATIVELY; O – THE ADHESIVE DEMONSTRATED POSITIVELY

Discussion

Beeswax is probably one of the oldest raw materials used by prehistoric humans, although direct evidence of it only comes from the Spanish Neolithic representations of bees and honey-hunting scenes in eastern Spain (Dams, 1978; Crane, 1983). In ancient times, this and other bee products such as honey and propolis were associated with a great deal of symbolism. They were valued not only for their magical origins in the nectar of flowers, which highly socialised bees transformed but also for their medicinal, antiseptic, or cosmetic properties (Regert, et al., 2001, Figure 1). Unfortunately, with the exception of these rock paintings and some later finds of the pre-Roman period, little is known about the use of beeswax in prehistoric times (Regert, et al., 2001, pp.549-550). Due to its properties, it is not preserved in archaeological materials, and its detection requires specialised chemical studies. In most cases, they are associated with mass spectrometry using gas chromatography (e.g. White, 1978; Regert, 2004). They show that beeswax may have been used to reduce pottery permeability (e.g. Charters, et al., 1995), but also to strengthen the resistance of various adhesives (e.g. Regert, 2004; Rots, 2008, p.50), even as early as the Middle Stone Age (see Kozowyk, Langejans and Poulis, 2016). The experimental research presented here showed that this may indeed have been the case. As the results proved, the beeswax greatly improved the performance of the pine resin by reducing brittleness. Intact, it survived the shooting tests of the ballistics experiment, demonstrating that it is a good adhesive that allows the arrow to last a long time. Aside from eliminating the brittleness of the binder, it hardens the glue, which can affect the duration of its preservation. The use of a mixture of resin and beeswax is, therefore very important for the pragmatic life of the bow and arrow user. Above all, it allows weapons to be used for a prolonged period of time. However, there is one disadvantage. The negative side of using this binder is the long setting time. Nevertheless, this may be due to too much beeswax being added during production. Therefore, an experiment involving the production and use of a resin with a proportionally different beeswax admixture will have to be carried out. Therefore, it is planned to carry out a larger experiment with more samples and excluding destabilising factors that would have eliminated variables and improved repeatability.

Conclusion

Beeswax is one of the most commonly mentioned additives for prehistoric adhesives. The present experiment set out to empirically test whether it actually affects the physical properties of natural binders. The production process showed that adhesives with beeswax additives have better bonding properties but a rather long setting time. Ballistic experiments, on the other hand, have demonstrated that they might be used as an excellent and long-lasting adhesives.

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Keywords bee
glue

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Gallery Image

FIG 1. FIG. 1. PINE RESIN GATHERED FROM TREES. PHOTO BY A. CETWIŃSKA

FIG 2. PINE RESIN: A) PINE RESIN FRESHLY GATHERED; B) STICKY-LIQUID PINE RESIN WITH NATURAL ORGANIC INCLUSIONS. PHOTO BY A. CETWIŃSKA

FIG 3. PINE RESIN WITH BEESWAX ADMIXTURE: A) PINE RESIN FRESHLY GATHERED; B) STICKY-LIQUID PINE RESIN WITH NATURAL ORGANIC INCLUSIONS; C) A LUMP OF BEESWAX. PHOTO BY A. CETWIŃSKA

FIG 4. PINE RESIN WITH CHARCOAL ADMIXTURE: A) STICKY-LIQUID PINE RESIN WITH NATURAL ORGANIC INCLUSIONS; B) LUMPS OF CHARCOAL; C) SMASHING PROCESS; D) ADDING SMASHED CHARCOAL TO THE PINE RESIN; E) STICKY-LIQUID OF PINE RESIN WITH CHARCOAL ADMIXTURE. PHOTO BY A. CETWIŃSKA

FIG 5. PINE RESIN WITH CHARCOAL AND BEESWAX ADMIXTURE: A) STICKY-LIQUID PINE RESIN WITH NATURAL ORGANIC INCLUSIONS; B) LUMPS OF CHARCOAL; C) SMASHED CHARCOAL; D) A LUMP OF BEESWAX; E) STICKY-LIQUID OF PINE RESIN WITH CHARCOAL AND BEESWAX ADMIXTURE. PHOTO BY A. CETWIŃSKA

FIG 6. BIRCH TAR HEATED ON THE STONE FROM THE HEARTH. PHOTO BY A. CETWIŃSKA

FIG 7. ARROW SHAFTS MADE FOR BALLISTIC EXPERIMENTS. PHOTO BY A. CETWIŃSKA

FIG 8. HAFTED LATE NEOLITHIC ARROWHEADS WITH DIFFERENT ADHESIVES: A) PINE RESIN; B) PINE RESIN WITH BEESWAX ADMIXTURE; C) PINE RESIN WITH CHARCOAL ADMIXTURE; D) PINE RESIN WITH CHARCOAL AND

BEESWAX ADMIXTURE; E) BIRCH TAR. PHOTO BY A. CETWIŃSKA

FIG 9. THE APPEARANCE OF AN ARROWHEAD WITHOUT THE ARROWHEAD, AFTER SHOOTING A SPECIMEN FROM A HEAVY BOW. THE IMPACT REMOVED THE ARROWHEAD AND MOST OF THE BINDER (PINE RESIN WITH CHARCOAL AND BEESWAX ADMIXTURE). PHOTO BY A. CETWIŃSKA

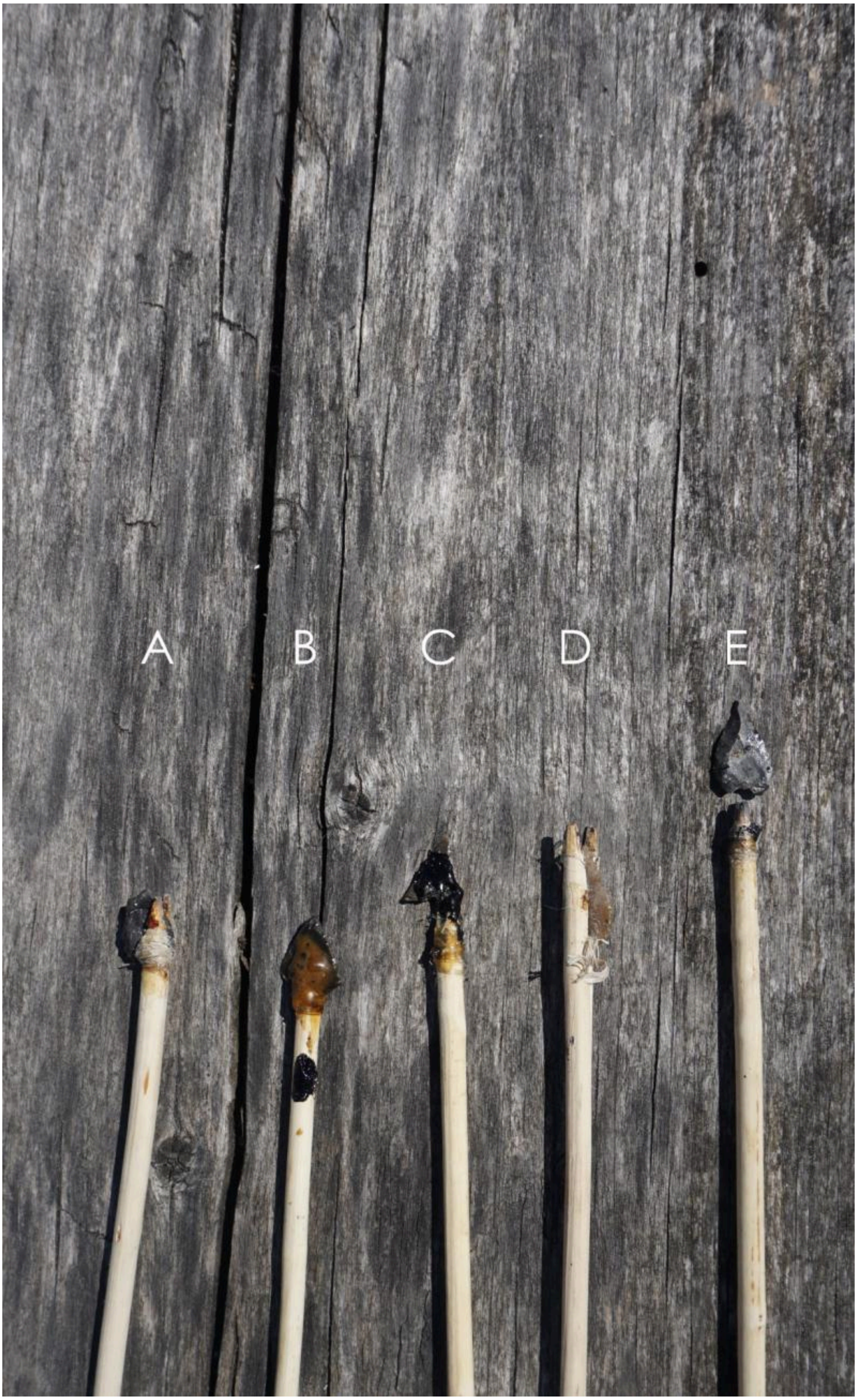

FIG 10. ARROW SHAFTS AFTER THE BALLISTIC EXPERIMENTS: A) PINE RESIN; B) PINE RESIN WITH BEESWAX ADMIXTURE; C) BIRCH TAR D) PINE RESIN WITH CHARCOAL ADMIXTURE; E) PINE RESIN WITH CHARCOAL AND BEESWAX ADMIXTURE. PHOTO BY A. CETWIŃSKA