Diet in the Past: Acorns as a Plant Food Resource: An experimental archaeology study in Leidse Hout, the Netherlands

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Bachelor Thesis June 2023

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13-6-2023

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Subtitle: An experimental archaeology study in Leidse Hout, the Netherlands

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Bachelor Thesis 2023 (1083VBTHEY)

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Leiden, 13-06-2023, Final

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Chapter 1: Introduction

Meat eating has been the focus of the field of diet and evolution in archaeology in the past and present. However, the current consensus, made possible by new and improved methods and techniques in archaeology, is that plant food resources played a role in the diet of our species (Schnorr, 2016). However, botanical remains at archaeological sites do not tell us about the energy expenditure during the gathering of resources. This is an important factor to consider when studying diet. If the cost of gathering resources is low and the benefits high, it is an optimal resource (O'Connell and Hawkes, 1981).

In non-human animals, natural selection favours strategies that have a low cost and high benefit. Gathering these resources results in a higher survival rate. Spending too much energy on resources can be unfavourable for the survival of a species (Hawkes et al., 1982). The optimal foraging theory can help explain the cost and benefits of subsistence patterns and can help to understand why foragers gather certain resources. In short, it is a predictive model that tries to understand what resources foragers would have gathered based on the needs of the foragers. There can be multiple resources available in a habitat, but not all resources are worth gathering. If energy efficiency is an important need or factor for a forager, optimal foragers would consider the energetic costs and benefits of a resource before they gather it and only gather the resource with the most efficient foraging strategy for them available in a habitat (Hawkes et al., 1982; Henry, 2017).
During this project, the energy expenditure of volunteers during an activity of acorn gathering was measured to understand the energy efficiency of the gathering process. Archaeological evidence of acorns has been found at multiple sites (Šálková et al. 2011) and we know that the nuts were an attractive food resource because they are nutritious, easy to gather, and easy to store (Morales et al., 2015; de Hingh, 2000). Nonetheless, not a lot of research has been done on the energy expenditure during the gathering process. One previous study, conducted by Prado-Nóvoa et al. (2017), showed that gathering acorns would have been profitable for hominins living in Spain millions of years ago. Oaks are distributed all over the world (Gil-Pelegrín et al. 2017) and also appear in Northwest Europe. Gathering acorns might have been more or less energy efficient in different environments than in Spain thousands of years ago. Thus, it is worth studying these nuts in different environments to understand more about the energy efficiency of the resource.

This topic/question can be explored with the help of experimental archaeology. Experimental archaeology is a way of reconstructing the past by combining archaeological evidence with new data created by testing and trying the topic or material that you want to know more about (Souyoudzoglou-Haywood & O'Sullivan, 2019). The Prado-Novoa study showed that experimental archaeology can help us understand the costs and benefits of acorn-gathering activities. This thesis

will expand the knowledge on the energy efficiency of the gathering process of acorns in the past by conducting an experimental archaeological experiment collecting the nuts and measuring the energy expenditure of the volunteers. Two standard energetic measurements will be calculated and compared to different activities to understand the intensity of the activity. This will hopefully increase our current knowledge about the optimal foraging potential of acorns and to understand more about diet in the past.

The main question of the thesis is *'How can an experimental archaeology approach help us understand diet in the past as explored through a study of acorn collecting?'*. This question will be answered with the help of a few sub-questions:

- *'What is the current understanding about food choices and consumption of plants in human evolution?'*
- *'How much energy does it take to collect acorns in a modern-day park in Northwestern Europe?'*
- *'Given these energetic costs, what would we expect for foraging patterns among ancient populations?'*
- *'How effective is this study on the collection of acorns for interpreting the past?'*

We expect that experimental archaeology can help us understand diet in the past because it can answer questions about the energetics and foraging potential of plant foods, in this case, acorns, which were yet little explored as a valuable food resource. The results of this study will show that gathering acorns is efficient due to the low energy expenditure during the collection of the resource and the high caloric return rate. This makes the resources more favoured by foragers that want energy efficient resources.

This thesis is divided into multiple chapters. Chapter two will be an introduction to the current knowledge about diet in the past with a focus on acorns. The methods and the data will be explained in detail in chapter three. In chapter four, the results will be calculated and these will be further elaborated in chapter five by comparing them to other studies. Chapter six will be the discussion, in which we will talk about the foraging pattern in the past and conclude on how efficient this study was for interpreting the past. In the last chapter, the conclusion, all arguments will come together to answer the main research question.

Chapter 2: Plant food resources in the human diet

Studying food choices and the consumption of plants in human evolution is not an easy task. There are multiple gaps in the archaeological record due to bad preservation and the nature of organic material: decomposition after death. Recently, new methods brought new lines of evidence of our plant food history. Moreover, looking at contemporary foragers might also answer questions about our past. In this chapter, we will answer the research question: '*What is the current understanding of food choices and consumption of plants in human evolution?'*.

2.1 Plant food history of our species

The archaeological record is a patchwork of evidence of the past. Diet is a very important topic because it is considered a driving force in our human evolution (Sponheimer et al., 2013). Unlike densely-mineralized animal organic material such as bones and teeth, organic material from plants decomposes after death and rarely gets fossilized. Therefore, animal consumption is much better represented in the archaeological record (Schnorr, 2016). However, plants are a necessary addition to our diet and should not be overshadowed by meat consumption. Plants contain, for instance, plant oils, starches, proteins, vital micronutrients (Bradbury and Holloway, 1988; Alasalvar and Shahidi, 2008), and vitamins like vitamin C (Milton, 1999).

In short, two types of botanical remains can be found at a site: micro- and macro-remains. Macro-remains are, for instance, shells, seeds, and legumes. Micro-remains are pollen, phytoliths, and starches and are not visible to the naked eye. Both can be preserved at sites and give valuable information about the subsistence of the past (Schnorr, 2016). Micro-remains preserve much better than macro-remains but were not widely studied till recently, because of their invisibility. New techniques that developed in the last few decades, like the identification of these micro-remains, tooth micro-wear analysis, stable isotope analysis, and dental calculus analysis, have improved the research on our plant food history and opened a new debate about the importance of plant food resources. We can now investigate remains that were never detected before in the record and understand more about the ecology and diet of humans in the past (Schnorr, 2016).

2.1.1 Diet in prehistory

To begin the overview of the diet in our past, we must start with our last common ancestor with the great apes. Great apes, like chimpanzees, occur in the wild in forests in Africa. Their diet consists mainly of leaves, insects, and fruits (Newton-Fisher, 1999). Our common ancestor was probably a

higher primate whose diet was mostly plant-based, but with some supplements like animal meat (Copeland, 2009; Konner and Eaton, 2010).

Early hominins in Africa had a shift in their diet ca. 3.5 million years ago (Sponheimer et al., 2013). This shift can be seen in the carbon isotope ratios found in the tooth enamel of early hominins. Stable carbon isotope ratios track $\delta^{13}C$ values in terrestrial plants. $\delta^{13}C$ values reflect three types of photosynthesis: C3, C4, and CAM. C3 plants have lower $\delta^{13}C$ values than the other two and consist mainly of trees, temperate grasses, and herbaceous plants. CAM plants have a $\delta^{13}C$ value between C3 and C4 plants and include plant species such as cacti and succulents. Lastly, C4 plants have the highest carbon isotope ratio. The plants of this group appear in open habitats and are usually tropical grass species and sedges (Schoeninger, 2014). Animals also have carbon isotope ratios in their bodies and receive these by eating terrestrial plants. An animal that eats mainly C3 plants will have an isotope level that corresponds to that value (Sponheimer et al., 2013).

Around 4 million years ago, early hominins had a C3 isotope-dominated diet, comparable to that of contemporary chimpanzees. However, it can be seen in the carbon isotope ratios of ca. 3.5 million years ago that hominins began eating C4 plants. Some hominins broadened their diet with these new plants, others started a completely new diet. This shift translates into the occupation of a new kind of habitat for hominins: the savanna. This shift is important in our evolution (Sponheimer et al., 2013), because it meant a change in habitat, moving out of the rainforest, and the exploration of new kinds of foods.

Diversity is important and advantageous in the diet (Hockett and Haws, 2003). Species that combine multiple food sources (e.g. plants, marine, and animal resources) in their subsistence have an advantage over species that are restricted to a single resource. Around 2 million years ago, the climate and environment changed in Africa and grasslands started replacing closed habitats, like rainforests (Cerling, 1992). It can be argued that hominins would not have survived if they had not shifted towards a broader and more variant subsistence, ca. 3.5 million years ago, and learned how to survive in the open grasslands (Ungar et al., 2006).

Early *Homo* came to the evolutionary scene in Africa ca. 2.3 million years ago with the appearance of *Homo habilis* and later *Homo rudolfensis*. There is no consensus about the key ingredients of their diet. An old, but still used, theory is that with the spread of the savanna landscapes, forest resources became more scarce and grassland ungulate species became more abundant. Early *Homo* started adding more meat to their diet, with the help of the development of new toolkits and technologies (Ungar et al., 2006). The increase of meat in the diet of early *Homo* would have been a driving force in human evolution, increasing our brains (Aiello and Wheeler, 1995) and social relationships (Eaton et al., 2002). Some experts even argue that meat was the most important ingredient in the diet of the Homo erectus (Ben-Dor et al., 2011).

However, others argue that new toolkits and technologies would have been created and used to gather and process plants. It has been theorized that tubers could have been more important than meat, due to their high availability and nutritious value, and increased the life-history and social relationships of *Homo erectus* (O'Connell et al., 1999). Digging tools would have been manufactured to dig for deeply buried tubers.

H. erectus, but also early *Homo*, would probably not have been able to leave Africa if it had not been capable of eating different kinds of resources (Ungar et al., 2006). The diversity of the diet was advantageous to survive in the different kinds of environments they would encounter when they left Africa. Unique evidence for this diverse diet and the consumption of plant food resources has been found at the Acheulian site Gesher Benot Ya'aqov, Israel, dating back to 780k years ago. The mid-Pleistocene hominins who lived at this site left behind an assemblage containing many macro-botanical remains, and aquatic and terrestrial fauna. The plant taxa that were found reflect the use and knowledge of different plant foods, the environment, and cooking (Meland et al., 2016).

Like the diet of *H. erectus*, and early *Homo*, the diet of Neanderthals has also been thought to be of large animal game, supplemented by some nutrients from plants (O'Connell, 2006), in contrast to the diet of modern humans in the past. This view has been challenged in recent times. New evidence from dental micro- and meso-wear shows a more diverse Neanderthal diet (El Zaatari et al., 2011; Fiorenza et al., 2011). A systematic study analyzing plant microremains of both modern humans and Neanderthals concluded that both species consumed a comparable arrangement of many different kinds of plant foods, even low-ranked ones (Henry et al., 2014).

2.1.2 Diet of modern-day foragers

Another way to research food choices in the past is to look at contemporary foragers and compare their food choices to the evidence that was found in the archaeological record. There is no consensus on the plant-animal subsistence ratio in modern foragers. Using the Ethnographic Atlas to understand the plant-animal ratio leads to the conclusion that most foragers (ca. 73%) derive their main subsistence from animal foods (>56-65%) (Cordain et al., 2000). However, it has been argued that the book Ethnographic Atlas is not a good source for understanding the diet of foragers (Crittenden and Schnorr, 2017). Nutritional research was not the focus of the book and there is no consistent measurement that connects the studies. Some studies measured the food in weight. Other studies used energy content as a standard. It is hard, or even impossible, to compare different measurements. Moreover, not every study recorded the same amount of data. Some studies were more intensive than others. Most studies that are done on the diet of contemporary foragers are snapshots of a specific tribe in a specific climate. A complete picture of the diet of humans is hard to

create, due to the use of different methods by researchers while researching the tribes and the different kinds of climates with their associated plant species.
Crittenden and Schnorr (2017) have tried to integrate all of the evidence that is provided using comparable methods to create a systematic overview. They concluded that foragers in circumpolar regions have a diet dominated by meat, but foragers in other climates, such as tropical climates, have usually a more plant-food-dominated diet. This can still differ per season because the kinds of plant and animal foods and the amount that is eaten vary per season (Crittenden and Schnorr 2017). Most sources do agree that foragers had a diverse diet, consisting of different kinds of hunted and gathered food sources depending on the climate where they live.

2.2 Acorns as a plant food resource

Although there is a discussion on the animal-plant subsistence rate, it is evident by looking at archaeological and anthropological evidence that plants were eaten in the past as a food resource. This project will focus on the foraging potential of one plant food resource: the acorn.
Acorns grow on oak trees (*Quercus* sp.), and have a broad geographic distribution. Oaks are usually deciduous trees with green leaves, but some evergreen kinds exist (Eaton et al., 2016). Multiple oak species are native to all kinds of different climates in different parts of the world (Gil-Pelegrín et al., 2017). Each has its lifecycle and distributes a different kind of acorn. The genus *Quercus* is divided into two subgenera *Quercus* subg. *Quercus* (New World) and *Quercus* subg *Cerris* (Old World). However, species from the subg. *Quercus* can still be native to other parts of the world (Denk et al., 2017). Oaks have been part of the folklore of different cultures and have provided resources like wood and food in the past and present (Gil-Pelegrín et al., 2017). In the present age, acorns are not commonly eaten in Northwest Europe. Nonetheless, in California and some parts of the Middle East and North Africa, acorn nuts are part of the diet of humans (Bainbridge, 1987). The acorns can be processed into flour to make bread, or eaten as a soup or mush (Bainbridge, 2006; Mason, 1992). Acorns were considered an attractive plant food resource due to their abundance, high nutritional value, easy harvest, easy storage, and long shelf-life (Aura et al., 2005; Bainbridge, 1987; Bettinger et al., 1997; De Hingh, 2000).

We know from anthropological sources that acorns in California have been an important plant food staple in the past for Native Americans. It is calculated that the oaks in California could have sustained a population of ca. 1.9 million in the pre-contact era. However, the acorns that were used by the Native Americans have a high amount of tannins and needed intensive processing to be made

edible. This resulted in a late appearance of an intensive acorn-based economy (Bettinger et al., 1997).

Likewise, the archaeological record shows that there is no doubt that acorns were gathered in the past as a food resource (Šálková et al., 2011). As told before, due to preservation, macro-remains do not always preserve at sites. When the nuts are found, it is usually in the charred form, due to contact with fire (Kislev et al., 1992).

The oldest evidence of acorns as a food resource was found at a site in Israel. At Gesher Benot Ya'aqov, palaeobotanical and lithic evidence for acorn processing during the Early-Middle Pleistocene has been unearthed (Goren-Inbar et al., 2002). The lithic evidence consisted of an assemblage of multiple tools to crack open nuts. This combination of evidence is special for a site from the Pleistocene. Mammals, like pigs, have acorns in their diet and would have been competitors of hominins. This competition would have forced the hominins to keep track of the ripening seasons and to know when to harvest the nuts before other animals came. Keeping track of seasons and time is a skill humans evolved to outcompete other animals (Goren-Inbar et al., 2002). Moreover, gathering acorns could have been more energy efficient for foragers, because the nuts have a lower competition rate than hunting. Hunting brings involvement with dangerous carnivores, like lions, as competitors. For acorn gathering, the competitors would have been smaller mammals, like pigs or squirrels (Prado-Nóvoa et al., 2017).

It is unknown whether acorns were a main focus in the diet of humans or not. At the Mousterian site Kebara cave in Israel, charred shell fragments of different *Quercus* sp. were found (Lev et al., 2005). Acorns were part of the subsistence of the people living in the area. However, the amount of charred acorn remains at the site compared to the other botanical macro-remains is low. Thus, it is more likely that acorns were a supplement to the diet of legumes of the inhabitants of Kebara rather than the full focus of the foragers (Lev et al., 2005). At the cave site of Santa Maira in Spain (ca. 12000-9000 BP) the opposite evidence has been found. Acorn macro-remains have been collected in multiple archaeological levels (Upper Magdalenian, Epi-paleolithic, and Mesolithic), and were one of the most frequently recovered botanical macro-remains found at the site (Aura et al., 2005). The focus of acorns as a part of the subsistence would have differed per site and region.

Evidence of acorns as a plant food resource is not restricted to the Middle East. Acorns have also been found at archaeological sites in temperate Europe. Waterlogged and charred acorn remains of *Quercus*, including *Quercus robur* have been found at a Late Mesolithic Ertebolle settlement called Tybrind Vig, Denmark (Kubiak-Martens, 1999). This is the oldest evidence of acorn processing that has been found in temperate Europe. In the Netherlands, acorn remains have been found at the sites: Esserveld (van Zeist, 1970), and Aartswoud (Pals, 1984). During research on the botanical

remains of archaeological sites from Northeast France, Luxemburg, and the Netherlands, it was discovered that acorns, together with Hazelnuts, were the most commonly gathered species in the botanical record of the investigated Bronze and Iron Age sites (2000-500 BC) (De Hingh, 2000).

To conclude, plant consumption has been overshadowed by meat consumption in our record due to a lack of evidence. However, new techniques have increased our knowledge of plant remains, and several lines of evidence show that the human species had a diverse diet that not only consisted of aquatic and terrestrial fauna but also different kinds of plant foods. This diverse diet would have been more advantageous due to more nutrients and a wider subsistence range. Whether they supplemented their diet with plants, or whether it was a main part of their diet is still a discussion. Evidence of acorn consumption can be found in archaeological records since the Pleistocene. Multiple lines of evidence, archaeological and anthropological, suggest that acorns would have been gathered and eaten as a plant food resource in Europe and other regions of the world in the past. The nut is easy to gather and store, high in nutrients, abundant, and had a long shelf-life.

Chapter 3: Methods and Data

In this chapter the methods and data of the experiment will be explained.

3.1 Location and acorns

On multiple days ranging from the middle of October until the end of October 2022, 11 volunteers participated in an acorn collection experiment in Leidse Hout, a public park in Leiden. The park covers an area of 18.5 ha and is planted with several kinds of standard Dutch trees, including oaks, ash, beech, and alders. During the preliminary investigation of this experiment, a location in the park with mostly oaks was picked as the central point for the experiment (coordinates: 52.176035, 4.476743).

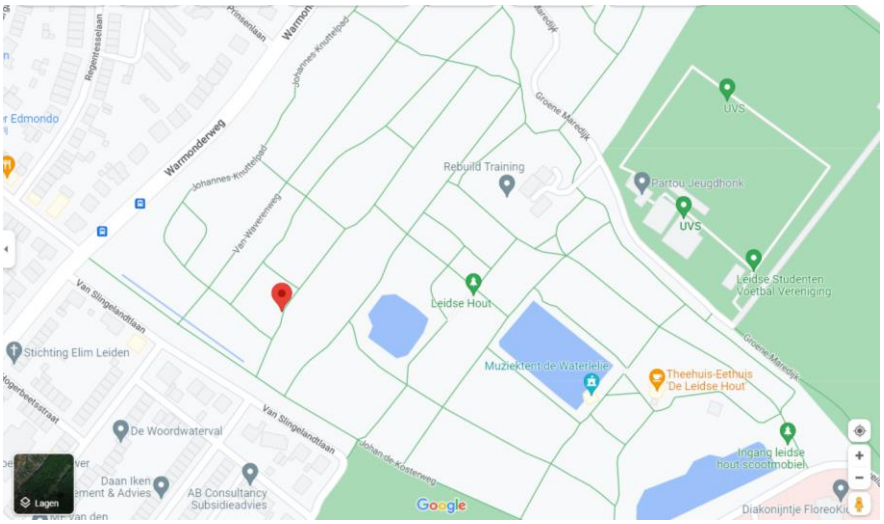

Figure 1: Leidse Hout in Google Maps. The red marker is placed on the spot where the acorns were gathered during the experiment (Google, www.google.com/maps).

The acorns that were gathered at the park originated from a native oak species in the Netherlands, the English oak, (*Zomereik* in Dutch, *Quercus robur*). This oak species has an extended distribution and can be found across most of Europe. The oak grows its leaves late in the year, around late April and early May. The fruit of the English oak are called acorns. They are variable in size, a bit rounded, and have longitudinal stripes when they are ripe (Eaton et al. 2016). Acorns are seasonal nuts. They ripen in mid-autumn and fall to the ground in September and October (Fleischhauer, 2008).
The chosen location in the park had a high concentration of acorns on the ground in October. Acorns were chosen to be gathered as a plant resource due to multiple reasons. The nuts are seasonal and nutritious (Salková et al. 2011). The oak trees drop a large amount of acorns and the gathering of

these nuts is not invasive. It only involves picking up the nuts and scattering them back on the ground at the end of the experiment.

3.2 The Experiment

Bachelor and Master students of the Faculty of Archaeology in Leiden could volunteer in September to help with the experiment in October. Groups of two or three volunteers were formed and became research assistants. These assistants were given an explanation about the experiment and the research devices at the faculty and then had to find participants who would gather acorns in the public park. The group of assistants would assist and guide the participants during the acorn-gathering experiments. The goal of the experiment was to measure the VO2 of the participants during the collection of acorns for twenty minutes.

The experiments took place in the morning. The day before the experiment, the assistants had to pick up the equipment bags at the faculty. The bags contained a VO2 master device, a Garmin Fenix 3 smartwatch, camp supplies, cleaning material, and food for the participants. The bags had to be brought to the park, and the research assistants had to install all the equipment before the participants arrived. The study design was approved by the Ethics Committee of the Faculties of Humanities and Archaeology at Leiden University (Letter 2022/14). All participants provided their Free Prior and Informed Consent. When the volunteers arrived at the site, they had to sign this form.

The VO2 Master Pro (https://vo2master.com/) was the main device used during the experiment. It is a portable metabolic analyzer that can measure oxygen consumption (VO2) (Toulouse et al. 2022, 119-20). It contains a mask with a device and a heart rate strap. It is a great device for this project due to its small size and affordability. Moreover, tests run by the manufacturer concluded that the device has high accuracy. This is acknowledged by other experts. Vondrasek et al. (2020) agreed that the validity of the device is acceptable for field-based research. However, there are some disadvantages. The device could only be calibrated when the temperature was above 15 °C. Furthermore, the VO2 Master is not resistant to water, and thus the experiment could only be done on dry days. Subjects were also not allowed to talk with the mask on because this could also wet the device.

The VO2 Master measured the VO2 levels of the participants during the activity. VO2 is the maximum volume of oxygen that a person uses per unit of time. It is a means of measuring the effort of physical activities (Garmin Blog, 2022). The more physical effort an activity takes, the more oxygen your body needs, and so the higher the VO2 level. Measuring the VO2 is an easy way to compare the energy expenditure of different people or groups. In this thesis, we will compare the energy

expenditure of men and women and calculate the MET value and kcal. There are different ways of expressing energy expenditure, but the MET value and kcal are two of the most standard energetic measurements. The MET value is a ratio that tells us about the intensity of activity while removing the effects of underlying metabolic differences between the volunteers. Kcal tells us how many calories were spent per individual collecting the acorns. The gathered amount of acorns was measured in kcal to understand the return rate of the resource. How to calculate these standard energetic measurements will be explained in chapter three. The outcome given by the energetic measurements will be used to compare the activity of gathering acorns to other activities.
The device had to be connected via Bluetooth to an app on a smartphone. In this app, data about the participant must be imported to measure the correct VO2 and heart rate. The app also assists with the calibration of the device and, after the experiment, displays the recorded data, which can be exported as files to analyze the data on the computer.

Initially, the subjects were not allowed to eat before or during the experiment, as they had to remain in a fasting state. However, the VO2 master only functioned in a dry climate with a temperature above 15 °C, which was not the case for the mornings last October when the temperature was lower. Therefore, the decision was made to perform the experiments during the early afternoon, allowing the subjects to have breakfast beforehand.
Each participant was given a unique ID number. Personal information about weight, age, height, and sex were collected and entered into the VO2 device (Table 1). Each subject carried two devices during the experiment: the VO2 master mask with an associated heart rate strap, and a smartwatch. The data used for this research was taken only by the VO2 master, while the smartwatch was used as a backup device for heart rate.

Table 1: Details of the participants

ID	SEX	BIRTHDATE (DD/MM/YYYY)	WEIGHT (KG)	HEIGHT (CM)
ACE_001	F	36917	50	168
ACE_002	M	37390	80	177
ACE_003	M	34550	87	187
ACE_004	F	36661	73	172
ACE_005	F	36113	70	163
ACE_007	M	36844	80	177
ACE_008	M	36044	65	173
ACE_010	M	36157	71	171

The experiment had two phases: the resting metabolic rate (RMR) and the collection phase. Both phases were measured independently. In between the two phases, there was a short break during which the participants were allowed to remove the mask from their faces and drink water if needed. All the subjects wore the VO2 mask, and heart rate strap, and watch during both phases. If the subject gave permission, parts of the experiment could be filmed.

The first phase that was recorded with the device was the RMR. During this phase, the heart rate and oxygen levels of the volunteers at rest were measured. The data created during this phase is needed to calculate exactly how much energy was spent on the collection of acorns. Even in a non-active state, the human body spends energy on internal processes, for instance, digesting food. By calculating the RMR, we can remove the energy expenditure of the body at rest from the data. The 'left-over' amount is the energy that was spent by the volunteers during only the activity.

The subject had to sit in a chair for approximately 15 minutes and was not allowed to move or talk.

The second phase was the collection phase. During this part of the experiment, the subject had to collect fallen acorns from the ground for approximately 20 to 25 minutes. The subject was allowed to move however they wanted, but talking was still not allowed. The subjects were given containers in which they could put the collected acorns. When the container was full, the subject had to give it to one of the research assistants, and an empty one was given back so that the subject could continue collecting the acorns.

After the second phase, the mask, heart rate strap, and watch were removed, and the data was saved. The weight of the collected acorns was measured, and then the nuts were scattered back into the field. The subjects were allowed to talk again, and their experience of the experiment was recorded on video or written down. The research assistants asked the subject about the easy, hard, and surprising parts of the experiment, whether they were comfortable or not, and what may have influenced their collecting abilities during the experiment.

3.3 The data

After the experiment, all data was gathered for analysis. The VO2 master and smartwatch data were downloaded as Excel files, and the video interviews were transcribed. The VO2 master measured various data, such as location, distance, and temperature. However, only the VO2 (ml/kg/min) data during the RMR and collection phase was necessary for the energetics research. The VO2 is the amount of oxygen the body consumes at the moment of measurement. This variable can be used to calculate energy expenditure and it tells us how intensive the acorn-collecting activity was.

In total, eleven subjects participated in the experiment, but unfortunately, not all the data was collected correctly. The data of three subjects were fully distorted, and the data of the other eight

subjects were also not always correct. Distorted data was removed from the Excel sheets to run the calculations. For instance, a zero in the columns in the Excel sheet meant that the data was not recorded by the VO2 master. These had to be removed from the data sheets of all the subjects because the statistical program that was used detected the zeros as recorded data.
Following that, significant gaps in the record, that can be seen during a first glance at the data of each subject, are explained here for clarity. The VO2 of subject 1 during the RMR was not recorded for the first five minutes. Subject 2 has no VO2 data during the RMR, but the VO2 data during the collection was recorded. Compared to the first two subjects, subject 3 has a very high VO2. This makes the subject an outlier compared to the rest. The VO2 data of subject 4 is very high. The VO2 of subject 8 was not recorded during the RMR until minute 11. This means that the data only shows the last four minutes of the RMR. The data of subjects 6, 9, and 11 is fully distorted and thus cannot be used.

An acorn-collecting experiment in a public park was carried out by 11 volunteers. They created data about the energy expenditure of gathering acorns from the ground. Two phases were measured: RMR and collection phase. Unfortunately, the data is a bit distorted, due to multiple reasons. In the next chapter, the data will be calculated into kcal and MET.

Chapter 4: The results

A few different kinds of statistics and calculations were run with the data: the difference between men and women, the MET, Kcal and the return rate of the acorns. The result of the calculations of these statistics can be used to draw parallels between this and other studies.

4.1 Summary statistics

The data analysis was done with R Statistical Software published on 31-10-2022 (v4.2.2; R Core Team, 2022) in combination with R Studio. The summary statistics mean, median, and interquartile (25% to 75%) for both RMR and collecting VO2 (ml/kg/min) were calculated in R and put into a new table in Excel.

These tables are separated into RMR (table 2) and collection (table 3) and also contain the ages and sex of the individual. The variables (table 4) for this research were created by calculating the differences in VO2 and HR between the RMR and collection. For instance, CollectingMean – RMRMean = variable. Calculating the variable by subtracting the data of the collecting from the data of the RMR tells us something about energy consumption on an individual level. In the table below, the calculated variables can be seen.

ID	MEAN VO2	MEDIAN VO2	Q1 VO2	Q3 VO2
ACE_001	2.719	2.63	2.4	2.94
ACE_002	NA	NA	NA	NA
ACE_003	15.58	15.7	17.5	13.93
ACE_004	3.712	3.455	3.225	4.018
ACE_005	2.918	2.915	2.765	3.07
ACE_007	3.29	2.99	2.38	3.87
ACE_008	3.282	3.185	2.842	3.542
ACE_010	3.492	3.53	3.11	3.84

Table 2: RMR phase VO2 data

ID	MEAN VO2	MEDIAN VO2	Q1 VO2	Q3 VO2
ACE_001	3.28	3.095	2.215	4.388
ACE_002	4.114	4.11	3.01	5.3
ACE_003	8.957	9.3	8.19	9.72
ACE_004	9.855	9.82	8.652	11.018
ACE_005	5.928	5.8	5.26	6.6
ACE_007	6.949	6.56	5.735	7.83
ACE_008	5.023	4.955	4.385	5.82
ACE_010	7.341	6.92	6.25	8.37

Table 3: Collection phase VO2 data

ID	MEAN VO2	MEDIAN VO2	Q1 VO2	Q3 VO2
ACE_001	0.561	0.465	-0.185	1.448
ACE_004	6.143	6.365	5.427	7
ACE_005	3.01	2.885	2.495	3.53
ACE_007	3.659	3.57	3.355	3.96
ACE_008	1.741	1.77	1.543	2.278
ACE_010	3.849	3.39	3.14	4.53

Table 4: Variables VO2 data

A t-test showed that the VO2 data is not normally distributed. The P-value was lower than $\alpha = 0.05$. A non-parametric test was done to compare the mean variable v02(activity)-vo2(RMR) between the males (n=3) and females (n=3). Unfortunately, the differences between different age groups cannot be calculated, due to all the participants having a similar age, with only one outlier. Because the sample is less than 40 (n=7), the Mann-Whitney U test was used.

The Mann-Whitney U test is a two-sample independent non-parametric test. We test, with a significance level of > 0.05, that:

- H0: The men and female are equal;
- Ha: The men and female are not equal.

This gives us W=4 and P = 1. We cannot reject that men and women are equal and so we do not know whether there is a difference in gender in the VO2 mean. The data from our study shows that men and woman spent an equal amount of energy during the gathering of acorns.

4.2 The MET Value

To understand more about the intensity of the activity, we can calculate the metabolic equivalent of task (MET) of acorn gathering (Ainsworth et al. 2000). The MET value of an activity is calculated by dividing the collecting mean by the RMR mean. By dividing instead of subtracting, a ratio is calculated that tells us how much energy is expended per unit of time, which is corrected for the underlying differences in resting metabolic rate between individuals. The values are scaled from light (MET< 3) to intensive (MET > 6) activities (Ainsworth et al. 2000). The MET can be used to compare acorn gathering to different activities and to understand whether it is less or more intensive than other day to day activities.

ID	MET VALUE
ACE_001	1.21
ACE_004	2.65
ACE_005	2.03
ACE_007	2.11
ACE_008	1.53
ACE_010	2.10
TOTAL:	**1.94**

Table 5: MET value

As can be seen in table 5 the average MET was 1,94. This means that collecting acorns is a light activity. The difference in MET between males and females is very low. The female participants had on average a MET of 1,96 (N=3) and the male participants 1,91 (N=3). Mann-Whitney U test did tell us that this difference is not significant enough.

4.3 Kcal and the return rate

Another method to understand more about the energy expenditure of the activity is to calculate the kcal, which is commonly referred to as calories. In this case, it means the number of calories that were burned during the activity of acorn gathering. Kcal is the number of liters of oxygen that is spent per minute. For this, a new variable has to be created. The VO2 master recorded the VO2 in ml/kg/min, as previously used, and ml/min. To create the L/min, the mean of the ml/min per subject was calculated and divided by 1000. Each participant spent 20 minutes collecting and so the kcal spent per minute was multiplied by 20. The data collection of participants 2 and 3 went wrong during the RMR phase. Fortunately, the ml/m can be calculated using the weight of the individual and a standard of 3.5 (Janet, 2021).

ID	AMOUNT OF ACORNS GATHERED	KCAL/MINUTE	KCAL/20 MINUTES	KCAL IN ACORNS
ACE_001	5024 gr	0.037975	0.7595	19,443 gr
ACE_002	2390 gr	0.24546	4.9092	9249 gr
ACE_003	1000 gr	1.97022	39.4044	3870 gr
ACE_004	3935 gr	2.27054	45.4108	15,228 gr
ACE_005	3995 gr	1.053835	21.0767	15,460 gr
ACE_007	2650 gr	1.465505	29.3101	10,255 gr
ACE_008	NA	0.56605	11.321	NA
ACE_010	4490 gr	1.366665	27.3333	17,376 gr

Table 6: Kcal per minute, 20 minutes and in acorns

Table 6 shows that it differs per participant how much energy they spent collecting the acorns. Acorns have an energetic absolute return rate of 3.87 kcal per 1 gr (Prado-Nóvoa et al., 2017). The amount that was gathered per subject can be found in Table 6.

During the 20 minutes the volunteers gathered acorns, each volunteer spent on average 22.4 kcal. The group gained 90,881 kcal in acorns. However, there is no data on the amount of gathered acorns for subject ACE_008. To make up for this we will add the average of the total to the sum. This gives us (90.881/ 7)* 8=103,864 kcal in total. Every volunteer gathered around 12,983 kcal in acorns during their 20 minutes activity. This is a high caloric return compared to the amount of kcal the volunteers spent collecting the nuts.

However, it can be seen in Table 6 that some volunteers have a much lower kcal expenditure than others. The kcal total of volunteers 1 and 2 is less than half the amount of the total kcal of the other volunteers. This is, compared to the difference between the other volunteers, high. It can be argued that volunteers 1 and 2 are outliers, but due to the small sample size, it cannot be statistically concluded that they are. However, for this small research, the difference is too high to take them into account calculating the average. Removing them from the data tells us that each volunteer spent 29 kcal gathering the acorns for 20 minutes and gained 12,438 kcal in nuts. A different kcal can be seen by removing the two outliers. These outliers could have been natural, or something might have gone wrong while gathering the data.

The difference in kcal between the males and the females is, like the MET, very low. Men (N=4) have an average of 26.8 kcal in 20 minutes (= 1.34 kcal/m). Females (N=2) spent 33.2 kcal during the 20 minutes (=1.66 kcal/m), but the Mann-Whitney U test did tell us that this difference is not significant enough.

In conclusion, the participants spent a low amount of kcal during the gathering of the acorns but gained a high amount of kcal in acorns as a plant food resource. The activity has a low MET value and is therefore a low-intensity activity. The Mann-Whitney U test suggests that there is no significant difference between men and women. In the next chapter, the results of the different calculations in this chapter will be discussed and compared to other studies.

Chapter 5: Parallels with other studies

The calculation of the MET, kcal, and summary statistics was done to assess the energetic costs of acorn collection and enable us to compare acorn collecting to other activities. We can now say that acorn gathering is a light activity during which not a lot of calories are burned. In this chapter, we will further answer the research question '*How much energy does it take to collect acorns in a modern-day park in Northwestern Europe?*', by questioning if there is a difference between the sexes and comparing the data to other activities.

5.1 Acorn gathering in another environment

The acorns were gathered in Northwest Europe. The standard climate of this geographical area is temperate. The most common trees are deciduous and evergreen trees (Caudullo et al., 2016). However, oaks do not only grow in temperate climates. There are multiple species of oak trees. Only one other study has been done on the energetic costs of collecting acorns. Prado-Nóvoa et al. (2017) studied the gathering of acorns in Spain in an area explained by them as a mid-latitude European (Mediterranean) environment. The research is based on the availability of the holm oak or evergreen oak (*Quercus ilex* L.) in the past. The researchers used a couple of different devices and methods to measure energy expenditure during the RMR, such as a Master Screen CPX JAEGER and indirect calorimetry. In the field, they used a GPS watch and an Oxycon Mobile JAEGER portable device to measure the collection phase. There were four collection phases: abrupt load, abrupt no load, flat load, and flat no load. Abrupt means that the activity was done on terrain with high elevation. The two flat phases were done on terrain with low elevation. On these two terrains, nine females had to pretend to pick up acorns with and without carrying a load of 3kg. The energy expenditure of the subject is different during the four phases. Prado-Nóvoa et al. (2017) conclude that gathering acorns is a moderate activity (The MET during all four phases is higher than 3) with a more favourable return rate than hunting.

We agree that the return rate of gathering acorns is high and thus favourable. However, our study has a different conclusion on the MET. The results of this study showed a MET of 1.9, compared to a MET higher than 3 in the study of Prado-Nóvoa et al. (2017). This might be explained by the different environments and methods. The energy efficiency of gathering acorns as a plant resource might differ per environment.

5.2 Other activities in modern populations

Although not a lot of studies have researched the costs of gathering acorns, we can compare the energy expenditure to other different kinds of activities in modern populations.

5.2.1 The MET value

A MET value of 1.9 meant that the activity was light. Ainsworth et al. (2000) made a compendium of physical activities. In this compendium, multiple activities, small and large, are listed with their according MET score, for instance, bicycling, walking, painting nails, and doing house chores. The bulk of the activities in the compendium has a higher MET value than 2. The compendium tells us that activities such as cooking and food preparation, playing a musical instrument like a cello and accordion, standing, making the bed, and light walking (less than 2<mph) have the same MET score as gathering acorns in a park. The walking speed data of the participants was not collected, however, due to the high amount of acorns on the ground, the participants did not have to walk far to gather them. So it is understandable that the MET value is low.

5.2.2 Activities of modern-day foragers

Gallois and Henry (2021) studied the cost of gathering among modern-day foragers. In Southeastern Cameroon lives a forager-horticulturalists group called the Baka. They are a mixed economy society, relying on multiple subsistence strategies. Gallois and Henry (2021) calculated the MET of plant food gathering of individuals in this tribe using GPS trackers. They concluded that gathering plants is more costly than hunting and fishing in the Baka tribe. The MET values of all three are above 6 and gathering is the highest with a value of 6.82. The difference in MET values between the two studies might be due to the different terrains and the distance traveled.

There is no difference in energy expenditure between the male and female volunteers, during the acorn gathering experiment. Pacheco-Cobos et al. (2010) researched the energy expenditure on the gathering of mushrooms in an indigenous Mexican community. They state that the energy expenditure between men and women is task-dependent, because of a difference in special ability. Women have, for instance, a lower energy expenditure for gathering activities than men. Men excel more in activities such as hunting. They support this argument with an experiment. Men and women gathered mushrooms and it turned out that men had a higher energy expenditure and mean heart rate than women. Moreover, the women found more different kinds of mushroom species and visited more collection sites. This is a different outcome than our study. In our acorn study, men spent 1.34 kcal/m and women spent 1.66 kcal/m. However, in the study of Pacheco-Cobos et al. (2010) men spent 5 kcal/m and women spent 3.2 kcal/m. Sarma et al. (2020) agree with Pacheco-Cobos et al. (2010) that there is a difference in energy expenditure between men and women. They studied energy expenditure in the BaYaka tribe and they argue that women have a lower energy

expenditure from daily work than men, because women have a more conservative energy expenditure in physical activity. They need a buffer for other important biological processes, like reproduction and fertility.

The difference in energy expenditure in this study and other studies can be explained by a couple of things. Collecting acorns could be a much lighter activity and thus the difference between the two sexes is close to none. Or, acorn gathering and other daily activities, such as mushroom gathering, are not comparable because the activity is too different. The mushroom gathering might be influenced by more factors than acorn gathering and the difference between men and women could be in that case bigger. Moreover, the time span of the experiment by Sarma et al. (2020), Gallois and Henry (2021) and Pacheco-Cobos et al. (2010) is larger than the time span of the acorn gathering activity. Lastly, the participants did different kinds of activities instead of one in the study of Sarma et al. (2020) and during Gallois and Henry's (2021) study, combined their activities most of the time to be more efficient. This might also explain the difference in energy expenditure.

In conclusion, the gathering of acorns in a public park in Northwest Europe does not cost a lot of energy, as shown by a low kcal and MET value. The activity is comparable in energy expenditure to standing or slow walking. There was no significant difference between the energy expenditure of men and women. The gathering of acorns in other environments and other foraging activities, such as mushroom gathering or different kinds of daily tasks, have a higher energy expenditure. This difference can be partially explained by the different methods and environments.

Chapter 6: Discussion

In this chapter we will discuss two different research questions: '*Given these energetic costs, what would we expect for foraging patterns among ancient populations?*' and '*How effective is this study on the collection of acorns for interpreting the past?'*. The previous chapters will be combined to tell something about patterns possible patterns of the acorn foragers. Moreover, we will analyze the research and consider if this study was comparable to the past and how to improve it.

6.1 Foraging patterns in the past

Archaeological evidence shows that acorns were gathered in the past. This project concluded that the energy expenditure during the gathering of acorns is low and the benefits of the are nut high. Foragers searching for energy efficient resources would probably have gathered acorns, if available in the region and season. It has an optimal foraging strategy, due to the high benefits and low costs. Acorns would probably not have been the main focus of the subsistence of humans. It is still a discussion whether plants were more important to the diet of humans than animal resources. The animal-plant subsistence rate is unknown for most sites and no lines of evidence from anthropological or archaeological sources have given us a definite answer yet. Acorn remains are diverse in their abundance in the botanical assemblages at sites.

6.2 A good study to assess the energy efficiency of gathering acorns?

Plant food was, and still is, important for the diversity of the diet of humans. This research contributes to the current knowledge in the field of diet and energetics, by studying the cost of gathering acorns. To summarize what has been said so far, acorns, if available, would have been a low-cost seasonal resource gathered by foragers in the past. A comparison between this and other projects showed that compared to other activities, gathering acorns in temperate Europe can be considered one of the lightest activities. There is a low difference between men and women, but the female volunteers did spend a bit more energy compared to the male volunteers.

As said before, experimental archaeology is a way of understanding the past by looking at archaeological evidence and trying to replicate it with an experiment to see how it works. In this case, we tried to replicate the collection activity of foragers to tell something about the energy expenditure. Although this study contributes to the current knowledge in the field of diet and energetics, it had its strengths and weaknesses in its methods and results. We should ask ourselves

how effective this experimental archaeology study on the collection of acorns was for interpreting the past.

6.2.1 The strengths

To start with the strengths, it was a simple experiment that people with little to zero experience could do. The assistants only needed a small explanation about the VO2 device and the setup of the experiment. The volunteers had to follow small and easy steps during the experiment. It was not an intensive activity, as was also shown by the data. This made the threshold to participate in this experiment low. Another strength of this experiment was the produced data. Calculating the kcal and MET is not difficult and it creates a good method to compare this activity to other activities done by different researchers. Moreover, the volunteers could move however they wanted during the collection phase of the experiment to make the collection of the acorns more natural.

6.2.2 The weaknesses

As for weaknesses, a few things made this study incomparable to the past. Firstly, it was a double-edged knife that the experiment was easy and could be done by volunteers who had no previous experience with the activity. The data of our subjects was compared to the volunteers of different studies. However, there is a gap in the knowledge between the different volunteers. The volunteers during the Pacheco-Cobos et al. (2010) and Gallois and Henry (2021) studies were all natives of the region and their energy level during their normal day-to-day activities was measured. Prado-Nóvoa et al. (2017) used volunteers who had never done the activity before, however, they did actively select volunteers based on the physical appearance of the SH hominin population they tried to study. In our study, there was no selection on age, body, and gender for our volunteers. This made the study inclusive, but it is questionable how comparable our data on energy expenditure is with the data of the other studies, and in the end, how comparable is it to the past. Because the volunteers were not trained, they all had different ways of picking up the acorns from the ground. Some volunteers sat down and gathered every nut around them. Others selected the acorns on how the nuts looked. This resulted in a random selection of acorns by the volunteers, instead of a structured selection by experts. Moreover, we explained in chapter two that men and women had different tasks in the past. This study researched both men and women. We saw a difference in their energetic level, with men spending less energy than women. However, as explained, other studies had a different outcome. Due to the false data and the study not having been done by experts, our data might not be an accurate representation of general patterns for acorn collection in the past. A couple of other explanations for the difference were given in chapter five. These were that acorn collecting is a much lighter activity and thus not comparable to other activities or that the periods of the activities were too different. Nevertheless, the low-level expert level of our volunteers might have caused our

research to be not comparable to the past.

Secondly, we only measured the energy expenditure of the collection phase and not the processing phase. Acorns have a high caloric return rate, but nuts contain a high amount of tannin and are thus inedible in raw form for humans. There are a few exceptions, like the acorns of the *Quercus ilex* subsp. *rotundifolia*, which can be found in the Mediterranean and can be eaten raw. However, most kinds of acorns in Northern Europe need to be processed before they are ready for human consumption (Mason 1992; Prado-Nóvoa et al. 2017). It is explained in chapter two that acorns were abundant in California, but the acorn economy started very late in the prehistory of the natives because it was very labour intensive to process the nuts. The energy expenditure of the processing part should also be researched to get a full picture of the foraging strategy of acorns as a plant food resource.

Thirdly, although the oak species *Quercus robus* occurs naturally in the Netherlands, all the trees in Leidse Hout are planted by humans to create a neat and spacious public park. This environment does not resemble the environment in which foragers would have gathered acorns. The park is divided into different zones, for instance, forest-like tree patches with little walking paths, open grass zones for walking and playing with dogs, and a sports field. At the place where the volunteers gathered the acorns, the oak trees were planted in a straight line. It was at the border of a forest-like tree patch and an open field. The experiment took place in October during the peak acorn harvest time of the year. The acorns were gathered in the field and all the nuts were visible and bare on the ground. The volunteers did not need to walk very far to gather a lot of acorns. So compared to the other gathering studies by Pacheco-Cobos et al. (2010), Gallois and Henry (2021), and Prado-Nóvoa et al. (2017) less energy was spent on movement and finding the nuts. The only energy that was spent was on picking up the acorns. This makes it plausible that the amount of kcal and the MET that was spent is comparable to slow walking. Moreover, the volunteers started and ended their activity at the gathering spot, while foragers would have walked back and forth from their camp to gather resources and would have combined this activity with other activities to be more efficient. This combination of activities can be seen in the study done by Gallois and Henry (2021). The cost of walking and searching for acorn-gathering spots also needs to be taken into account to tell something about energetics in the past.

Lastly, this study also dealt with a low amount of data and probably a high amount of false data. The data was explained in detail in chapter three. There were eleven volunteers in this study, but the data of three volunteers were not recorded and could not be used during the data processing. This brought the amount of useful volunteer data to eight. The data of these eight other volunteers were also a bit distorted but still useful. However, our conclusions might be different from the truth because of the distortions. Especially, more data is necessary to understand the difference between

men and women in kcal and MET value, because the outcome is different from other studies.
One of the reasons for the distortion was the climate. As explained in chapter three, the VO2 Master only worked when the climate was dry and the temperature was above 15 degrees Celsius. The temperature in October was unfortunately lower than 15 degrees and the device did not always want to calibrate. Therefore, some data might not have been recorded correctly.

All in all, in the current state, this experiment is incomplete. It needs to be improved in its methods to conclude about acorns and energetics in the past.

6.3 The improvement of the research

Now that we have explained the weaknesses of the experiment, we can try to understand how to improve it to make an evident conclusion about the energetics of gathering acorns in the Netherlands and compare it to the past. Especially if we want to compare this research on a grander scale to other studies. In this paragraph, a few different possible methods will be explained.

6.3.1 Different methods

A few of the problems with our methods were the location, the volunteers, and the climate.
First, for the location, the Netherlands has no natural forests anymore, but oaks have been planted in most woods. Leidse Hout did not have bushes or higher ground plants than grass in the area that we gathered, but forests are usually more patched with these sorts of small plants. Thus, gathering acorns would be harder in this environment and thus show a different energy expenditure for the collection of acorns. It would be interesting to research energy expenditure on different kinds of terrains. For instance, Prado-Nóvoa et al. (2017) did the same research on two different kinds of terrains, flat and with elevation, and compared them. Foragers would have gathered on different kinds of terrains and so this would improve the research.
Second, the research assistances can be given more information on the gathering of acorns to make the volunteers understand how to collect the nuts. A homogenous way of collecting the nuts could give more comparable data to other studies that used experts. Although freedom of movement created a natural way of collecting acorns for the volunteers, it might not represent how people gathered acorns in the past and it is difficult to compare experts to no-experts. Moreover, actively selecting volunteers based on the profile of foragers or early hominins would not make this research inclusive anymore, however, it can make the research more comparable to the past.
Third, the climate is impossible to control, but very important for the Vo2 master device. The experiment was planned to take place in the morning, but the temperature in the mornings of October was usually lower than 15 degrees Celsius (Huiskamp, 2022). Rain in October is not

uncommon (Huiskamp, 2022) and this also limited the days on which the volunteers could do the experiment. There are two ways to sort out this problem. A future experiment can be done in a warmer month, even though there are no acorns on the ground, and volunteers pretend to pick up acorns. Or the experiment can start at the end of September, to include more available days. There will be not as many acorns on the ground in September as in October, but the days will be a bit warmer and more volunteers can participate which will give us more data for the results. Both making experts of the volunteers and doing the research in a warmer climate will prevent some of the distortions that we experience now in the data.

Lastly, the period of the activity can be increased to understand more about the intensity of the activity. The studies of Pacheco-Cobos et al. (2010), Gallois and Henry (2021), and Prado-Nóvoa et al. (2017) encompassed a longer period for the activity. Twenty minutes might be too short to compare this study to other studies.

6.3.2 Edibility and the processing of the acorn

To tell something about the optimal foraging strategy of acorns, the energy spent during the processing of this nut should be taken into account (O'Connell and Hawkes, 1981). Processing the acorns to make them edible would also have cost energy. Currently, no study has been done on the energy expenditure during the processing of the nuts. There are many different kinds of processing methods, due to the many different cultures that made food out of nuts. However, not every process has been recorded. There are detailed sources about the preparation of acorns in North America, but not in Central America or Europe. In some regions in Mexico, the acorns were deemed inedible by the natives. The sources about other parts of the area are vague regarding whether the nuts were eaten or not. It is known that acorns were eaten in Europe, but the information is not detailed. The nuts were used as a 'last resource' in times of famine. Some sources mention the washing of the nuts or burying the nuts in the soil to remove tannins (see Mason 1992).

The most common way to eat acorns in Northwest America was to make flour from the nuts. The acorns were shelled and cracked to get the fruit. Then the fruit was ground to create the flour. The flour still contains tannin and it needed to be sifted with cold or hot water to remove the bitter taste and to make it edible. From this flour, bread, soup or mush could be made. In Northeast America, the acorns were shelled, boiled, leached, and then eaten directly, put into another dish, or made into flour (see Mason 1992).

The acts of grinding, shelling, cracking, boiling, burying, leaching, or sifting all take energy. Therefore the energy expenditure during the processing of acorns has to be studied to understand the value of acorns as a food resource.

In conclusion, acorns would have been gathered by foragers. It is an efficient resource due to its low cost and its high caloric return rate. However, we questioned the effectiveness of this study to compare it to the past. Due to the many weaknesses of the study, we should improve the study, before we can conclude anything about acorns as a food resource. This study did show that this topic is worth exploring more to understand diet in the past.

Chapter 7: Conclusion

The current understanding of food choices and consumption of plants in the past in human evolution is complex. Archaeological and anthropological evidence shows that plant food resources played a role in the diet of humans and our evolution. A diverse diet is advantageous for a species, but the animal-plant food subsistence rate is currently unknown. Plant food could have been a supplement or a main part of the diet. Archaeological evidence shows that acorns were eaten by humans from the Pleistocene onwards. Acorns are an abundant, but seasonal, resource that is easy to gather and store and has a low competition rate. The nuts have a high nutritional component, however, they need to be processed before they are edible for humans.

The experiment took place during the peak of the acorn season. Eleven volunteers participated in an acorn-collecting activity with a VO2 master. The data that was created was occasionally distorted but did give us a first impression of the energy expenditure of humans during the collection of acorns. The participants spent a low amount of energy gathering the acorns in a modern-day park in Northwestern Europe. The Mann-Whitney U test showed no significant difference between the energy expenditure of men and women. The MET value of 1.9 showed that acorn collecting is a low-intensity activity. The volunteers spent ca. 29 kcal in the 20 minutes but gathered a high amount of kcal in acorns in return.

Therefore, compared to other activities, acorn collecting is a low-effort activity with a high caloric return rate. A previous acorn-collecting study done in a different environment concluded that collecting acorns is a moderate activity, as they had a higher MET value than this study. Thus, the energy efficiency of gathering acorns depends on the environment in which they are collected. Lastly, this study showed no differences between men and women in energy expenditure. The different MET values and cost of gathering between the studies can be explained by the different methods, terrains, length of the activity, level of expertise, and the number of activities.

So given these low energetic costs and the archaeological evidence, we would expect that foragers in search for energy efficient resources would have gathered acorns as a resource. The optimal foraging theory argues that the more efficient the resources, the more it is favored by foragers as an optimal strategy and thus foragers would have gathered acorns, if available, to add to their subsistence.

Unfortunately, this research had some weaknesses that need to be solved to make the study more effective. At the current state, this study on the gathering of acorns is not effective to help us understand the past. Future studies should use volunteers with a higher level of expertise on the subject, gather acorns in a different environment, measure the energy expenditure during the processing phase of the nuts, and increase the duration of the activity.

To answer the main question, ‘How can an experimental archaeology approach help us understand diet in the past as explored through a study of acorn collecting?’, This study explored the energy expenditure of humans during the collection of acorns in a public park. Archaeological evidence shows that the nuts were probably gathered by humans, if available, however, little was known about the energy efficiency of the collecting activity. With the help of experimental archaeology, data was created that show that acorns would have been a great addition to the diet of humans, due to a low-cost gathering process and a high caloric return rate. And, although the research has its flaws, the project showed that this topic is worth exploring to understand more about acorns and its role in the diet of humans.

Abstract

This study researched the energy efficiency of acorn collecting in the Netherlands through experimental archaeology. The goal of this project was to expand the knowledge about diet in the past. Diet is an important topic in archaeology, but organic material decomposes after death. This results in a gap in the archaeological record. The animal-plant subsistence rate is currently unknown, however, diversity is important for our diet and plants would have been a part of the subsistence of foragers in the past. According to the optimal forager theory, foragers use the most optimal resources in a habitat for their needs. The archaeological record shows that acorns were gathered by foragers, due to their many benefits. This study researched the energy efficiency of collecting acorns.

The experiment was performed in a public park called Leidse Hout in the Netherlands. Eleven volunteers gathered acorns from the ground, while their energy expenditure, their VO2 level, was measured during different phases with a portable VO2 master device. Two standard energetic measurements, MET value, and kcal, were calculated and compared to different activities and studies to understand the intensity of the activity.

A few conclusions could be made with the experiment data. Firstly, acorns have a high caloric return rate. Secondly, acorn collecting is, according to the low MET value, a low-intensity activity, comparable to slow walking and playing the cello. Thirdly, compared to other gathering activities, acorn collecting was the lightest. Lastly, this study showed no significant difference between the energy expenditure of men and women. Following the optimal foraging theory, foragers looking for energy efficient resources would have collected acorns, if available, due to the low costs and high benefits of the resource. This experiment archaeology project increased our current knowledge about the optimal foraging potential of acorns and showed that these nuts would have been a great addition to the diet of humans.

Keywords: experimental archaeology, energy expenditure, acorns, optimal foraging theory, foragers, diet

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