Extract from:

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Chapter 4 *Methods for Extracting Archaeological Remains from Dental Calculus*

The purpose of this project is to understand the dietary practices of the two populations at Tarbat and to determine if there were any changes in the diet over several centuries. In order to draw any conclusions about this, the formation of dental calculus and the level of attrition from each individual will be examined, as well as the examination of any starch granules that may have survived in the matrix of the dental calculus. In order to do this, it is necessary to remove and de-mineralize a sample of the calculus from each individual. If there are any remains trapped within the matrix, the demineralization of calculus will release them and make it possible for those materials to be examined. This project will explore how easy it is to confidently identify starch granules to plant species and will use those determinations in order to provide additional information about the carbohydrate portion of the diet. After all this information is gathered, it will be used to help determine if there were any differences in the diets of the monastic population and the medieval population. It will also be possible to determine if there are any differences between the diets of the males and females of either period. Firstly, this chapter will discuss the methods used to gather the necessary information in order to properly analyze the materials. It will then go on to discuss the analytical procedures implemented to help illustrate any conclusions. Lastly, this chapter will examine the variables that may have an impact on the outcome of the research project and the conclusions.

Methods

In May 2009, Cecily Spall and the Tarbat Discovery Programme provided fifteen adult individuals from both periods of occupation. Some individuals were represented by a complete mandible, others were fragmented mandibles, a few were fragments of the maxilla, and one individual was just represented by teeth. Every individual has some level of dental calculus formation on the tooth surfaces and the buildup could be described as light, medium or heavy build up. Overall, there were five medieval males, three medieval females, one male and one female from the early monastic period and four males and one female from the late monastic period (Table 4.1). Each individual was photographed before the calculus sample was removed (Appendix A). After the photographs were taken, the formation of the dental calculus was analyzed for each tooth from each individual (Appendix A). This was done in order to get an understanding of the severity of the calculus formation and to help determine which teeth would be used for the sampling of the calculus.

Period and Sex	Monastic Male	Monastic Female	Medieval Male	Medieval Female
Sample Numbers	F98, F93, F117, F140, F157	F152, F128	F45, F28, F75, F69, F74	F50, F62, F64

Table 4.1: A list of sample numbers for each individual organized by period and sex.

Two samples of calculus were used from each individual. In most cases, one sample of calculus was removed from the buccal surface and one sample was removed from the lingual surface. This was not possible for every individual due to the fact that some individuals did not have calculus formations on one or the other of those tooth surfaces. One individual, F74, had very heavy calculus formations that allowed for three samples of calculus to be taken. Individuals F157, F152 and F98 only had enough calculus formation for one sample to be taken.

After the calculus sample determinations (Appendix A), a small spatula was used to remove a small area of the calculus. Then forceps were used to place the calculus sample into a labeled eppendorf tube. The forceps and spatula were cleaned between each sample of calculus to avoid cross contamination. After all the calculus samples were removed from the tooth surfaces, the eppendorf tubes were filled half way with 0.6M of HCl in order to remove any soil residues and other unwanted contaminants. After ten minutes, the HCl was removed from each tube and new plastic pipettes were used for each sample. Next, each sample of calculus was ground into a powder using a mortar and pestle. A few drops of 0.6M of HCl were added to the powder and, using a plastic pipette, the materials were placed back into the proper eppendorf tube. As always, new pipettes were used for each sample and the mortar and pestle were cleaned with ultra pure water between uses.

After grinding each fragment of calculus, there were twenty-eight samples from the fifteen individuals. Each eppendorf tube was placed on the vortex for thirty seconds and then allowed to sit for two hours. This process was used in order to de-mineralize the calculus, thus leaving behind any materials that had been trapped within its matrix. After two hours, the samples were placed in a centrifuge at 13,000 RPM, for ten minutes. This forced the sample material to the bottom of the tube and allowed for the removal of the excess HCl. For this task, new glass pipettes were used for each sample to allow for more precise HCl removal and to avoid removing any of the materials from the bottom of the tube. The tubes were then filled half way with ultra pure water and placed back into the centrifuge at 13,000 RPM, for ten minutes. Then, as with the HCl, the water was removed from the tube with new glass pipettes for every sample. The process of adding ultra pure water and placing the sample tubes in the centrifuge were repeated twice to make sure all the HCl and other impurities were removed from the sample.

These materials were then ready to be analyzed. Exactly two drops of ethanol were added to each sample tube. The vortex was used for fifteen seconds to make sure all of the material from the bottom of the tube was mixed into the ethanol. One drop of ethanol was placed on a 22x22mm glass cover slip using a new plastic pipette for each sample. There are two reasons why ethanol was placed into each tube. The first being that the ethanol is needed to facilitate the removal of the material from the bottom of the tube. Secondly, ethanol evaporates very quickly. Therefore, after one drop is placed on the cover slip, the ethanol evaporates in a few seconds leaving behind the dry sample to be examined. While the ethanol was evaporating, one drop of glycerin was placed onto the center of a super frost plus microscopic slide (Thermo Scientific Menzel-Gläser). The slide was then flipped over and was firmly pressed onto the cover slip, making sure the glycerin and sample material were sandwiched in between. The slides were then labeled appropriately; any excess glycerin from the edges of the cover slip was removed; and the slides were allowed to sit for twenty-four hours. After the passing of this twenty-four hour period, the edges of the cover slip were sealed to the slide with clear nail polish.

These slides were not the only ones that were created at this time. Based on the plant macrofossils that were discovered at Tarbat, several modern starch sample slides were prepared. The purpose of making these slides was to use them as a reference to assist in the identification of any ancient starch granules that may be found in the Tarbat samples. As mentioned in the previous chapter, there were several plant materials from both the monastic and the medieval periods at Tarbat: barley, oats, wheat, rye, and fat hen.

Analytical Procedures

There are a few different approaches that will be used during the analysis of the findings. As stated earlier, the amount of dental calculus formation was analyzed for every tooth on each individual. This will help provide information about the diet and it is possible that a pattern could emerge linking the amount of calculus development with the presence or absence of starch granules. In terms of trying to locate starch granules from these individuals, two slides were made from every Tarbat tube sample to make sure the maximum amount of materials would be analyzed. Each slide was then examined under a microscope. Any starch granules that were discovered on the slide were photographed using a camera which was attached to the microscope (Olympus IX71 inverted microscope with fitted Colourview III camera). The microscope and camera were also linked to a computer; therefore the photography was captured by a computer program called Cell D (Digital Imaging Solutions, version 2.6). Each starch granule was photographed in polarized and un-polarized light to capture every detail needed in order to properly identify the starch to plant species. Each starch granule was also photographed at x10 and x20 magnification. The computer program, Cell D, is an important feature in the identification of the ancient starch granules. The program makes it possible to measure both the ancient and modern starch granules, which can assist in making comparisons between the two. It is also possible to zoom in more closely to the necessary details of the starch granules in order to make proper identifications. The identification of starch granules were assessed using the guidelines discussed in Chapter 1 (Piperno 2006, Torrence 2006).

A master's student, Shirley Curtis, from the University of Bradford has been conducting stable isotope analysis from the same fifteen individuals used for this study in ancient starch. Her results will be incorporated into the discussions and conclusions of the diet at Tarbat. As discussed in Chapter 2, some scholars have linked a diet rich in proteins with the formation of calculus, while a diet rich in carbohydrates is linked to the formation of dental caries. Her analysis is essential for determining if this is or is not the case as well as for the discussion of Tarbat diet.

Variables

There are several variables that may have an impact on the outcome of this research. Potentially, every bit of calculus could have starch granules surviving within its matrix. However, just because there is calculus formation does not necessarily guarantee that starch granules have survived within it. When it was decided which calculus samples were to be used for this project, calculus which was considered medium to heavy formations were chosen because it was assumed there was a greater chance of starch survival within larger formations. The researcher found it difficult to decide which samples to use because it was unknown which areas were better for the survival of starch.

Another variable is that each individual had either less or more calculus development than others. The calculus samples were chosen based on the heaviest build up of calculus, but is there really a correlation between heavy calculus formation and a greater number of starch granules within the matrix? Lastly, even though two samples of calculus were extracted from each individual and two slides for every sample were prepared, there was inevitably some material left at the bottom of the eppendorf tube that was therefore not examined. There is a possibility that there are starch granules within that material, but the time limitations of this project did not allow for it all to be examined or analyzed. These are all important factors to consider when examining the results.

By analyzing several different factors from each individual, a more complete picture of the dietary practices can emerge. Teeth are in constant contact with the environment and with food products; therefore it is not possible to ignore dental conditions when assessing the results of this project. Most importantly, the purpose of this project is to determine the carbohydrate portion of the diet. Although dental calculus, caries, and attrition are helpful in determining this information, it is the use of ancient starch research that will be a key factor in providing the necessary information to the search questions of this project. It will also be interesting to compare the stable isotope analysis with the overall dental conditions and starch granule survival from each individual.

Chapter 5 *The Analysis of Dental Calculus and Starch Granules Discovered from Tarbat*

After the extraction of materials from the dental calculus of the Tarbat individuals, the slides were placed under a microscope in order to determine if any starch granules were present. Of the fifteen individuals that were studied, starch granules were present in seven. The number of granules in each of the individuals ranged from one to three starches. Many of the starches that were discovered share similar characteristics in shape and size, which could indicate that they are from the same species of plant (color photographs of the starch granules can be found in Appendix A). This chapter will discuss the following five points. Firstly, it will discuss the number of starches that were discovered to have survived within the dental calculus of the Tarbat individuals. Secondly, the possible identifications of those starch granules based on their size and shape. Thirdly, there will be a comparison between the severity of calculus, sex, period of occupation and attrition with the presence or absence of starch granules. Fourth, this chapter will discuss if there is a possible correlation between calculus sampled from the lingual or buccal surfaces of the tooth and starch granule survival at Tarbat. Fifth, it will then go on to consider the stable isotope ratios analyzed by Shirley Curtis at the University of Bradford and how that information compares to the presence or absence of starch granules. This will be done in order to get a better understanding of the dietary practices of the monastic and medieval populations at Tarbat. Finally, this chapter will discuss any limitations encountered during the duration of the project.

Comparison of monastic males and females

As stated in the last chapter, this project analyzed seven individuals from the early and late monastic periods at Tarbat. These individuals were divided between the early and late monastic period. The early monastic period consisted of one male and one female while the late monastic period consisted on four males and one female. In total, five starches were discovered from an early monastic male, a late monastic male and a late monastic female (Table 5.1). One significant difference between the males and female is that there were three starch granules present within the calculus of the female, while the males possessed one starch granule each. In addition, the female had much heavier build up of calculus than the two males. It is difficult, however, to determine if this is of any significance because there was another male with the same severity of calculus formation as the female, and this individual did not have any starch granules survival.

Another significant correlation is that it seems the dental attrition is quite severe for the two males and one female with starch granule survival. Male F98 had especially heavy attrition on the premolars 1 and 2 which affected the roots and dental pulp of both teeth. This individual did have unusual wear patterns because although the premolars were severely affected, the molars showed only slight attrition. Male F117 featured severe wear on every tooth that was present, but especially on the premolars and molars. Finally, female F128 had severe wear on the few teeth that were present for this sample. The dentine was exposed on each tooth.

Sample Number	Age	Severity of Calculus	Sex	Starch presence	Attrition
F98	Unknown	Light	Male	1 granule	Severe
F152	46+ (King)	Light to heavy	Female	0 granules	Intermediate
F93	Unknown	Light to medium	Male	0 granules	Slight
F117	40-50 (Brothwell)	Light	Male	1 granule	Severe
F140	46+ (King)	Medium to heavy	Male	0 granules	Severe
F157	Unknown	Light	Male	0 granules	Intermediate
F128	Unknown	Medium to heavy	Female	3 granules	Severe

Table 5.1: Chart comparing the early (F98 and F152) and late monastic females and males in terms of severity of calculus, age and attrition with the presence or absence of starch granules. Age is based on Sarah King's osteological report (2000) or evaluated by Don Brothwell based on attrition of molars 1, 2 and 3.

Comparison of medieval males and females

This project also examined eight individuals from the medieval period at Tarbat. This period contained five males and three females. In total, eight granules of starch were discovered from four individuals (Table 5.2). It is significant to mention that all three females that were examined had starch granules within their dental calculus. There was only one out of the five males to have the survival of starch granules. There were three starches discovered in association with the male, while the females only had one to two starch granules survive. The medieval female, F64, is noted to have light to heavy calculus build up (Appendix A). During the analysis of dental calculus, it was noted that out of the four teeth present with calculus for individual F64, all had light build up of calculus on the buccal surface. The only areas with a considerable amount of calculus were the lingual surfaces of premolar 1 and premolar 2. Therefore, it could be stated that all three females had light calculus formation. It is also important to mention that the male who had starch granule survival possessed medium to heavy calculus formations. In other words, there was much more calculus buildup on the male with starch granules than the females.

Although there is a possibility of a correlation between the recovery of starch granules with severe dental attrition during the monastic period, the same could not be said for the medieval period. The discovery of starch granules during this period seems to be on teeth with all levels of attrition.

Sample Number	Age	Severity of Calculus	Sex	Starch Presence	Attrition
F45	Unknown	Light to medium	M	0 granules	Intermediate
F28	25-30 (Brothwell)	Medium to heavy	M	3 granules	Slight
F75	26-45 (King)	Medium to heavy	M	0 granules	Severe to Slight
F69	26-45 (King)	Light to heavy	M	0 granules	Severe
F50	Unknown	Light	F	1 granule	Intermediate
F62	27-30 (Brothwell)	Light	F	2 granules	Intermediate
F64	25-35 (Brothwell)	Light to heavy	F	2 granules	Intermediate to Slight

F74	35-45 (Brothwell)	Light to heavy	M	0 granules	Severe to Slight

Table 5.2: Chart comparing the medieval males and females in terms of severity of calculus, age and attrition with the presence or absence of starch granules. Age is based on Sarah King's osteological report (2000) or evaluated by Don Brothwell based on attrition of molars 1, 2 and 3.

Comparison of the presence of starch granules from both the monastic period and medieval period

There does seem to be a slight difference between the numbers of starch granules present in the monastic and medieval population (Table 5.3). There are five starches present from three monastic individuals, while there are a total of eight starches present from four medieval individuals. It does not seem that there is a correlation between the amount of calculus and the presence of starch for either population, nor is there a significant difference between the severities of calculus formation between the two periods (Table 5.3). It is also important to mention that out of the fifteen individuals examined, starch granules were discovered to have survived in the dental calculus from three males and four females. Therefore, there does not seem to be a significant difference in terms of starch granule survival between the males and females from Tarbat.

In addition, there does not seem to be a significant difference in the level of attrition between both periods of occupation. Both the males and females from the monastic and medieval periods range from severe to intermediate to slight levels of dental attrition.

Sample Number	Age	Severity of Calculus	Sex	Period	Number of granules	Attrition
F98	unknown	Light	M	Early monastic	1	Severe
F117	40-50	Light	M	Late monastic	1	Severe
F128	unknown	Medium to heavy	F	Late monastic	3	Severe
F28	25-30	Medium to heavy	M	Medieval	3	Slight
F62	27-30	Light	F	Medieval	2	Intermediate

F64	25-35	Light to heavy	F	Medieval	2	Intermediate
F50	unknown	Light	F	Medieval	1	Intermediate

Table 5.3: Chart comparing the medieval and monastic periods in terms of severity of calculus, age and attrition with the presence or absence of starch granules. Age is based on Sarah King's osteological report (2000) or evaluated by Don Brothwell based on attrition of molars 1, 2 and 3.

Comparison between severity of calculus, location of calculus sample and recovery of starch granules

As discussed in Chapter 2, the formation of dental calculus is a complex process and one that is currently not well understood. Therefore, an important part of this project was to determine if there was any correlation between the location of where the sample of dental calculus was taken and the presence or absence of starch granules. As demonstrated by the chart below (Table 5.4), there does seem to be a significant number of starches located on the lingual surfaces of the tooth. Of the eight samples of calculus with starch granules, seven were taken from the lingual surfaces of the tooth. There is only one sample with the survival of starch granules that was taken from the buccal surface of the tooth. In addition, twelve starches were discovered from the lingual surfaces, while only one starch granule was discovered on the buccal surface.

Sample Number	Severity of Calculus	Location of Calculus Sample Taken	Number of Starch Granules Present
F117-T17	Light	Lingual mandibular canine	1
F62-T11	Light	Lingual mandibular molar 3	2
F28-T4	Medium to heavy	Lingual maxillary premolar	3
F128-T24	Medium to heavy	Lingual mandibular premolar	1
F128-T23	Medium to heavy	Lingual mandibular premolar	2
F98-T22	Light	Buccal mandibular molar 2	1

F64-T13	Light to heavy	Lingual mandibular premolar 2	2
F50-T26	Light	Lingual maxillary molar	1

Table 5.4: Chart demonstrating the severity of calculus, the location of the where the calculus sample was taken and the presence of starch granules.

As stated in the previous chapter, one sample was taken from the lingual surface and one from the buccal surface of every individual, unless the build up of calculus or absence of calculus did not allow for that possibility. In addition, two samples were used from every individual, unless there were not enough teeth present or were not enough teeth with dental calculus present. Table 5.5 demonstrates the location of where the dental calculus samples were taken from the individuals with no starch granules present. It seems that even though there are a few samples taken from the lingual surfaces, a majority of the samples were taken from the buccal surfaces, or in one case, the mesial surface of the teeth.

However, because of the limited number of individuals and the limited number of calculus samples taken, it is difficult to determine if this is a significant observation. Further research would have to be under taken, but could potentially provide important information about the survival of starch granules and the possibility of improved recovery of starch by targeting the lingual surfaces of the tooth.

Sample Number	Severity of Calculus	Location of calculus sample taken
F157	Light	Lingual mandibular molar 3
F69	Light to heavy	Buccal maxillary canine and buccal maxillary incisor
F152	Light to heavy	Mesial maxillary molar
F45	Light to medium	Buccal mandibular incisor and buccal lingual canine
F93	Light to medium	Lingual mandibular canine and lingual mandibular premolar
F140	Medium to heavy	Lingual mandibular premolar 1 and buccal mandibular molar 3
F75	Medium to heavy	Buccal mandibular canine and lingual mandibular premolar 2

F74	Light to heavy	Buccal surface of canine, buccal surface of molar 1 and lingual surface of molar 3

Table 5.5: This chart demonstrates the location of the dental calculus sample for those individuals with no presence of starch granules.

Comparison of stable isotope ratios, the presence or absence of starch granules, the severity of dental calculus, and attrition

One way in which archaeologists can reconstruct diet is to determine $\delta^{13}C$ and $\delta^{15}N$ values of human bone collagen (Pollard *et al.* 2007: 182). These ratios provide information about the protein portion of the diet, and it is also possible to determine a reliance on terrestrial food resources or marine food resources through this analysis (Schoeninger *et al.* 1983). Shirley Curtis, from the University of Bradford, is currently conducting stable isotope analysis of bone collagen on several individuals from Tarbat, including the same fifteen individuals examined as a part of this project. The reason for this was to determine if there were any differences between in the individuals who had starch granule survival within dental calculus and those individuals without starch granule survival. As the chart below describes, there does not seem to be any difference in the $\delta^{13}C$ and $\delta^{15}N$ ratios between the individuals with starch and the individuals without starch (Table 5.6). The enriched nitrogen ratios, however, indicate that these individuals were consuming a large portion of protein through marine resources. According to Margaret Schoeninger *et al.* (1983), humans who consume a large number of fish have a $\delta^{15}N$ range between +14.3 and +22.9. All fifteen of the Tarbat individuals have nitrogen ratios which fall between these numbers.

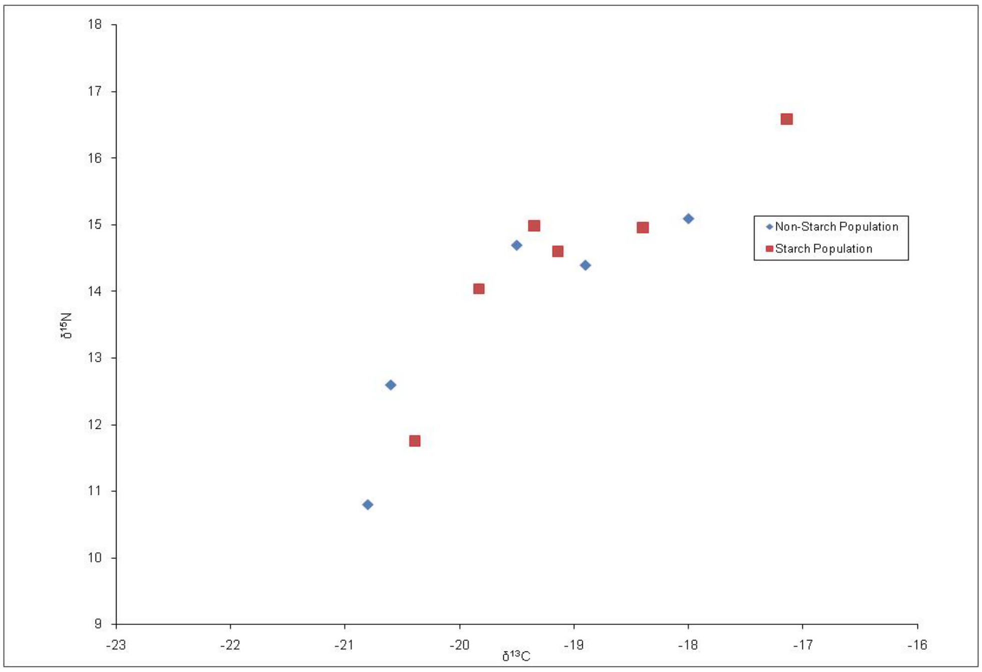
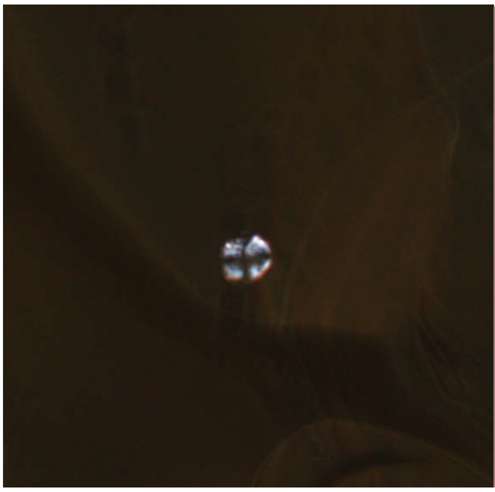


Figure 5.6: Graph comparing the stable isotope ratios from the individuals with starch and those without starch.

Starch Identification: Oats and Wheat

Many of the starch granules that were discovered were similar in shape and size, which could indicate that they are from the same plant species (Table 5.7, page 43). There were three starch granules discovered in the calculus of individual F28. Two of those starches are relatively the same in size and are considered round in shape. In addition, the cross and hilum are in the center of the granule. The shape and size of these granules are most similar to oat granules, but could also be considered very similar to the wheat granule (Figure 5.1).



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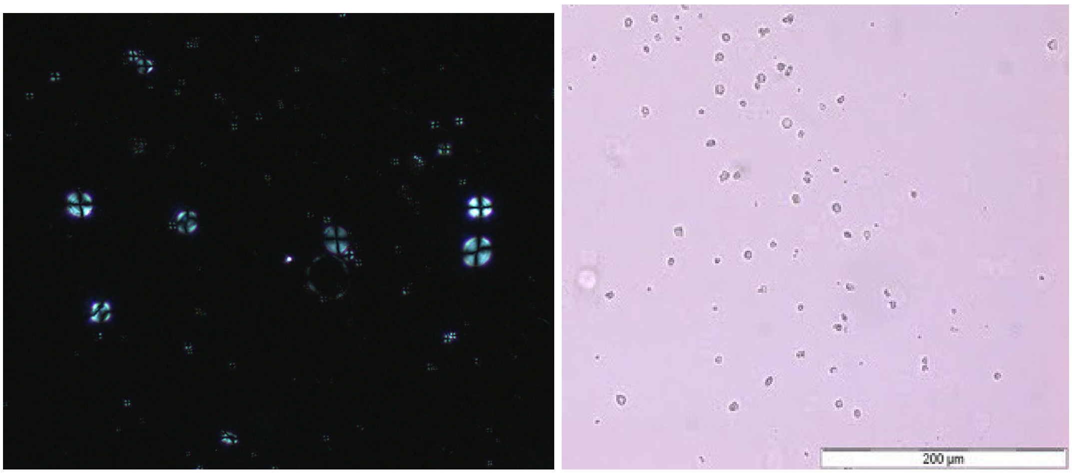


c *d*

Figure 5.1: a) and b) photographs of possible oat or wheat granules from individual F28 taken at x20 magnification (source: author). Starch a) measures 10.85µm and 9.87µm along the arms of the cross and starch b) measures 9.11µm and 10.28µm along the arms of the cross. These starches were identified after comparing them with c) a photograph of modern wheat granules (source: author). The starches were also compared with photograph d) of modern oat granules (source: University of York starch library). Both c) and d) were photographed under x10 magnification and scale bar applies to both c) and d).

According to a paper written by Piperno *et al.* (2004), the mean length of the wild oat species, *Avena barbata*, is 12 ± 2.9µm, while the mean length of emmer wheat (*Triticum dicoccoides*) is 17 ± 6.1µm. The sizes of both granules from F28 could fall within the ranges of either oat or wheat. The same could be said about the small round granules discovered from individuals F50, F64 and F128 (see Appendix A for photographs of starches from these individuals).

It is important to note that two granules of two different sizes were discovered attached to one another from sample individual F128 (Figure 5.2). According to Hardy *et al.* (2009), "cereal starches from wheat, rye, barley and triticale have a bimodal distribution: that is they have two granule sizes, type A and type B, which are unique to these cereals" (Hardy *et al.* 2009: 252). One starch was slightly larger than the other, but they are both round, and the size of the granules fall within the range of oat or wheat granules as stated by Piperno *et al.* (2004).

Oats were one of two main crops grown in Scotland for many centuries (Dickson and Dickson 2000: 234). Oats first appeared as a cultivated crop between the 1st and 3rd centuries AD (Fenton 1976: 27). This crop grows well in cool, moist conditions as well as poor soils and exposed land (Dickson and Dickson 2000: 234-

235).

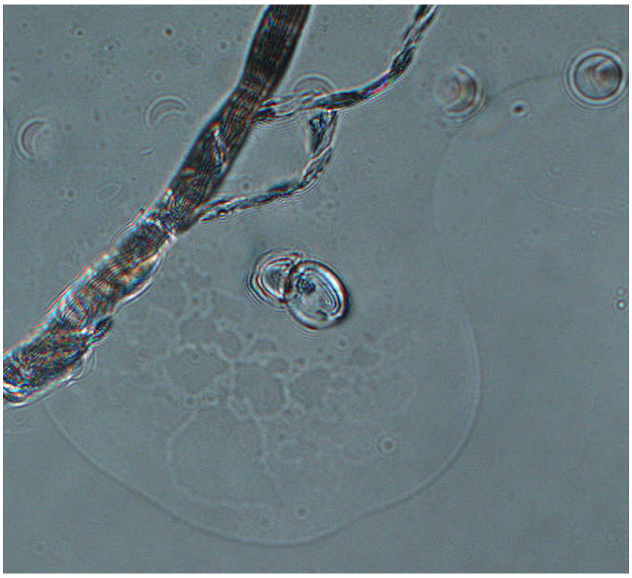
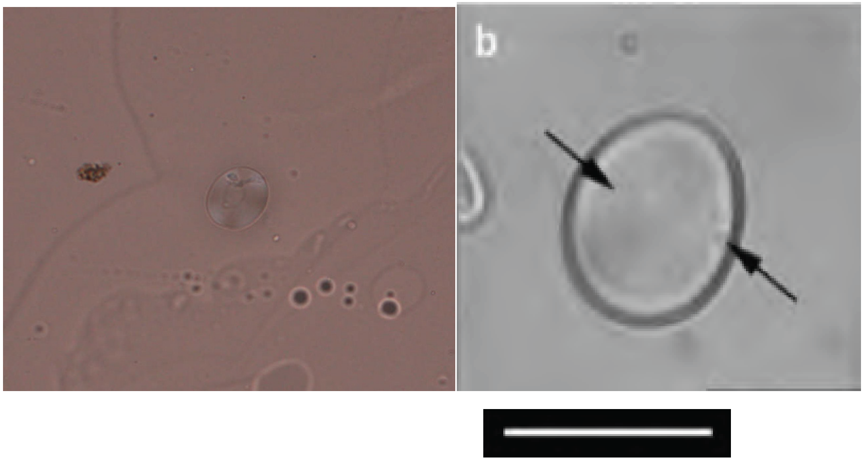


Figure 5.2: Photograph of two starches from individual F128 which are attached to one another (source: author). The larger one measure 13.72µm (length), 11.02µm (width)and the smaller one measures 10.20µm (length), 9.45µm (width).

Wheat has been discovered throughout Scotland at sites dating to the Neolithic period (Dickson and Dickson 2000: 237-238). Emmer wheat is known to have been a part of the Roman soldier's diet in Britain. However, this species of wheat is not commonly found in later periods after Rome's occupation of Britain (Dickson and Dickson 2000: 237-238). As mentioned in Chapter 3, the presence of wheat macrofossils discovered at Tarbat was unusual for Early Historic Scotland (Holder 1999). Wheat is a particularly nutritious crop because it contains both carbohydrates (60-80%) and proteins (8-14%) (Dickson and Dickson 2000: 238). It seems logical that the above mentioned starch granules from the Tarbat dental calculus are of either oat or wheat plant species since oats were such an important crop in Scotland and because wheat macrofossils were discovered at Tarbat.

Starch Identification: Barley

Of all the potential cereal crop granules discovered from the Tarbat samples, only one could be considered barley (Figure 5.3). The possible barley starch granule was discovered on individual F98. Although it is similar in shape to the granules identified as oat or wheat, this granule is much larger with a length of 15.09 µm and a width of 17.46 µm. According to the paper written by Piperno *et al.* (2004), other species within the barely genus have a much larger mean size than oat or wheat. The article states that *Hordeum spontaneum* has a mean length of 20 ± 4.7µm*, H. bulbosm* has a mean length of 17 ± 3.7µm*,* while *H. glaucum* has a mean length of 18 ± 3.9µm (Piperno *et al.* 2004).



a *b*

Figure 5.3: Photograph of possible barley granule from individual F98 (source: author) which measures 15.09µm in length and 17.46µm in width. This was compared with photograph b) of modern barley, Hordeum vulgare (Henry and Piperno 2008). Scale bar associated with photograph b, which is 25µm.

As discussed in Chapter 3, barley could be considered the most important crop in Scotland. This cereal has been cultivated throughout the area since the Neolithic period (Dickson and Dickson 2000: 231). It is a hardy cereal that can be grown in the diverse climate and environment of Scotland (Dickson and Dickson 2000: 233). Barley macrofossils were discovered often from both periods of occupation at Tarbat.

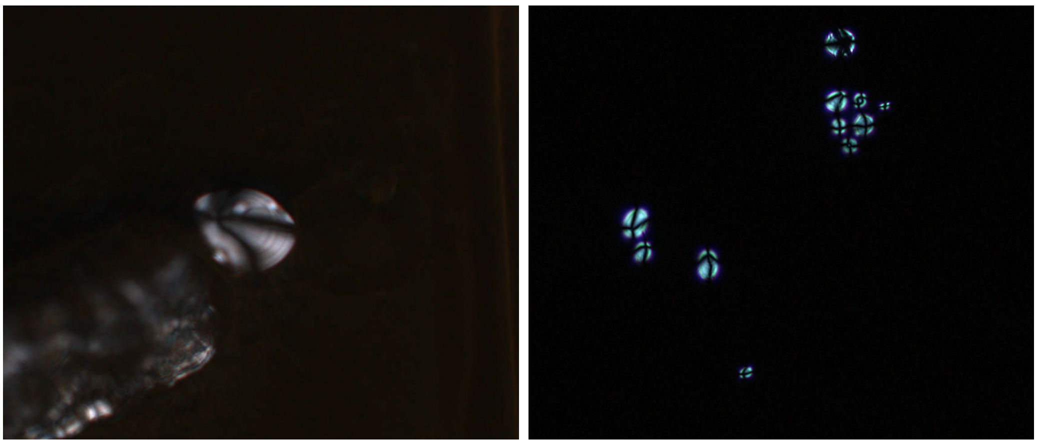
Sample Number	**Size of granule**	**Shape of granule**	**Possible Identification**
F28	27.61µm (length) 20.79µm (width)	Oval	Tuber
F28	9.11µm, 10.28µm	Round	Oat or wheat
F28	10.85µm, 9.87µm	Round	Oat or wheat
F50	9.53µm, 9.13µm	Round	Oat or wheat
F62	14.55µm (length), 11.23µm (width)	Oval	Bean
F62	7.32µm (length), 5.27µm (width)	Oval	Bean

F64	13.13µm, 13.69µm	Round	Oat or wheat
F64	5.80µm, 4.04µm	Round/slightly oval	Undetermined
F98	15.09µm (length), 17.46µm (width)	Round/slight oval	Barley
F117	11.27µm, 11.83µm	Round/bell-shaped	Undetermined
F128	13.82µm, 11.71µm	Round	Oat or wheat
F128	13.72µm (length), 11.02µm (width)	Round/slightly oval	Oat or wheat
F128 (attached to above mentioned granule)	10.20µm (length), 9.45µm (width)	Round/slightly oval	Oat or wheat

Table 5.7: This chart shows the measurements and possible identifications for each starch granule discovered in the dental calculus of Tarbat individuals. The measurements were taken for the length and width, or in the cases of round granules, measurements were taken along the arms of the cross.

Starch Identification: Tubers

Along with the two possible oat/wheat granules discovered within the calculus of individual F28, was a much larger oval shape granule. After comparing it to the starch granule library at the University of York, it was determined to be a tuber. Even though the ancient granule looks very much like a potato, it is not very likely to be one (Figure 5.4). The potato was introduced into Ireland between 1586 and 1588, but was relatively slow in spreading throughout England and Scotland (Stevenson 1951). The potato was not grown as a field crop in Scotland until 1739 (Stevenson 1951).

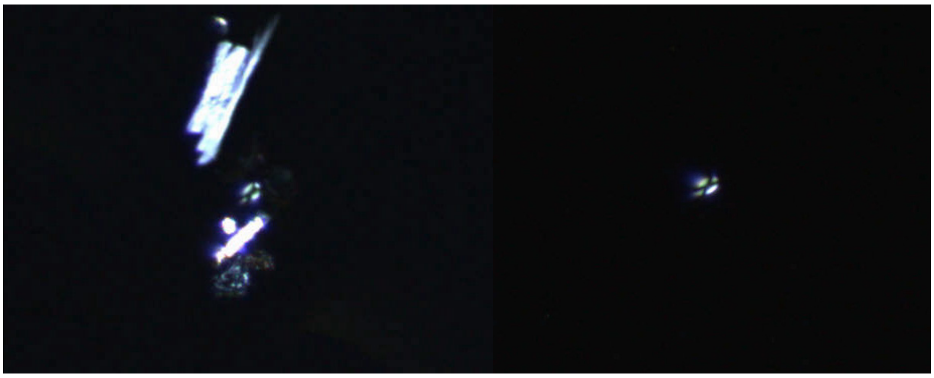


a *b*

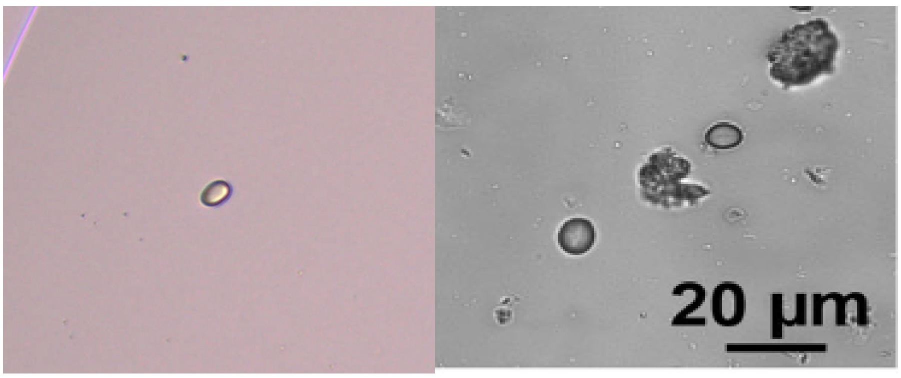
Figure 5.4: a) Photograph of a tuber from individual F28, which measures 27.61µm in length and 20.79µm in width (source: author). The identification of this granule was made after comparison with b) photograph of modern potato granules, which range in size from 19.59µm in length to 28.58µm in length, with the smallest granules not being measured (source: author). Photograph a) was taken at x20 magnification, while photograph b) was taken at x10 magnification.

Starch Identification: Beans

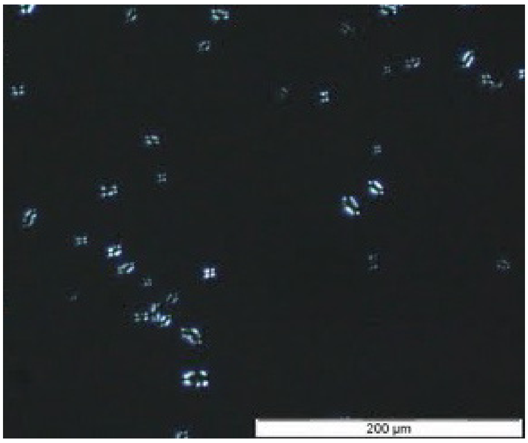
Lastly, the two starches found in association with individual F62, a medieval female, were small and oval in shape. After comparing these starches with the starch library at the University of York, it was determined that the two ancient starches most resemble mung bean (Figure 5.5). These two granules were also compared to current literature on starch granules and were found to be similar in size and shape to a South American legume tree with edible pods, *Inga feuillei*. Although it seems highly unlikely that a South American legume or an Asian mung bean would be present in medieval Scotland, there are a number of species of bean that could account for its presence. The broad bean, however, was a crop which was cultivated during the



a *b*



c *d*



e

Figure 5.5: Photograph a) of a possible bean granule from Tarbat, measures 7.32µm, 5.27µm along the arms of the cross (source:author). Photographs b) and c) are polarized and un-polarized examples of possible bean from Tarbat, this granule measures 14.55µm in length, 11.23µm in width (source:author). These granules were compared with photograph d) of Inga feuillei *(Piperno and Dillehay 2008) and photograph e) of polarized modern mung bean (University of York starch library).*

medieval period in Scotland. (Dickson and Dickson 2000: 229). According to Camilla Dickson and James Dickson, "the field bean is the forerunner of the broad bean which evolved from it in the early Middle Ages" (Dickson and Dickson 2000: 229). Beans have been grown in Scotland since the Neolithic period (Dickson and Dickson 2000: 229).

Limitations of the project

The short time period in which this project had to be completed was the major limitation that was encountered. This limitation could potentially have an effect on the results as well as the conclusions. Firstly, due to the limited time period, the researcher was only able to examine fifteen out of the one hundred and seventy-seven individuals at Tarbat. Because only a tenth of the population was examined, it could be difficult to formulate conclusions about the dietary practices. In addition, due to the time limitations, it was only possible to examine two samples of calculus from each individual. This could be a factor in the limited number of starch granules that were discovered. Lastly, it was only possible to compare the starch granules present in the Tarbat samples with macrofossils that were discovered at the site and with the small library of granules created by Richard Allen at the University of York. Because of the limited number of granules available for comparison, it was not possible to confidently determine the exact species or even plant type. The identifications were determined by size and shape, and in some cases the position of the cross and hilum but did not take into account other characteristics of the granule that could assist in the identification. This, again, had to do with the small library available and the limited time period in which to complete this project.

Chapter 6 *Conclusions and Future Research*

This final chapter will discuss the possible dietary practices of the monastic and medieval population based on starch granule research and stable isotope analysis. This chapter will then go on to discuss the difficulties with starch identification and the issues of drawing conclusions about diet based on a few starch granules. Finally, this chapter will discuss future research that could be explored to gain more significant results and conclusions.

Monastic and Medieval Diet at Tarbat

Fifteen individuals were examined from both periods of occupation at Tarbat, and only thirteen starch granules were recovered from seven individuals. Given the small population size that was studied and the limited number of starch granules found, the results discussed in the previous chapter are not statistically significant. The purpose of this project was to examine dental calculus, to determine if there were any ancient starch granules trapped within its matrix, and if so, could they be identified to plant species. Because of these research questions, all fifteen individuals had significant calculus build up. Therefore, it is difficult to determine whether or not the males and females from either period had any differences in diet because all fifteen shared a common dental condition. As discussed in the previous chapter, there were no significant differences in the amount of calculus build up or dental attrition between either periods or between either sexes.

Sarah King, who evaluated all one hundred and seventy-seven remains, mentioned a significant difference between the males and the females from the medieval period. According to her report (2000), the women tended to have more dental caries, while the men tended to have more calculus development. As discussed in Chapter 2, this could indicate that the women were consuming more carbohydrates than the men.

Out of the thirteen starch granules that were discovered, seven could be considered as either oat or wheat granules, while one could be possibly be identified as a barley granule (see table 5.7 on page 43). This seems likely considering that wheat, oat and barley plant macrofossils were discovered from both periods of occupation at Tarbat. In addition, based on the archaeological excavations, it was determined that both the monastic and the medieval populations were engaged in farming.

It is difficult to determine if there were any differences in the diets of the monastic and medieval populations based on the starch granule analysis because all the starch granules that were discovered were similar in shape and size. The only possible differences that could be mentioned are the tuber associated with F28, a medieval male, and two possible bean starch granules associated with F62, a medieval female. It is possible, however, to see a slight difference between the medieval and monastic populations when examining the stable isotope analysis of these fifteen individuals (Curtis pers. comm.). According to table 6.1, the medieval population has more enriched nitrogen ratios which indicate more of a reliance on marine food resources. However, the carbon ratios suggest that these individuals were consuming a mixed diet of both terrestrial and marine food resources (Curtis pers. comm.). According to the results from the monastic population, these individuals were consuming both terrestrial and marine food resources, while marine foods were not as heavily relied upon as in during the medieval period (Curtis pers. comm.). Shirley Curtis has examined twenty individuals from the monastic population and twenty individuals from the medieval populations and according to her results, this trend continues to be visible (Curtis pers. comm.)

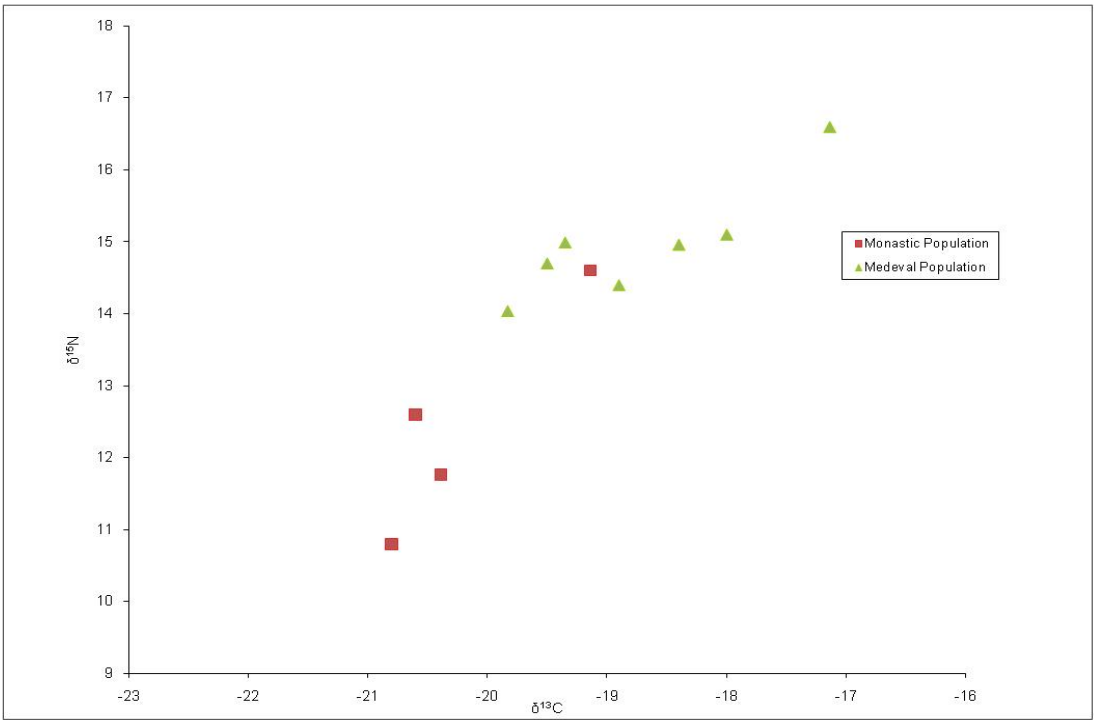


Table 6.1: Graph comparing the stable isotope ratios from the monastic period in compared to the medieval period.

Difficulties in starch granule identification

According to Judith Field, in the book *Ancient Starch Research,* a large library of starch granules is needed in order to make proper ancient starch granule identifications (Field 2006: 95). Because of the time limitations of this project, modern starch granules slides were created according to which plant macrofossils were discovered during excavations. In addition, the University of York has a small collection of modern starch slides which were used during the identification process. Although it is possible to compare the size and shape of the ancient starch with the modern ones, current studies have shown that each plant species has a variety of sizes and shapes and that there is a great deal of overlap between classes (MS *in prep*). Taking this into account, it is not possible to confidently identify the thirteen starch granules discovered during this project.

An experiment was conducted at the University of York in order to determine the difficulty in starch identification and to determine if starch granules could be identified correctly when using known samples. Nine different plant species were used in order to conduct this experiment: potato, maize, water chestnut, cassava, sweet potato, oats lotus root, mung bean and plantain. According to the results, plantain (79%) and potato granules (70%) were usually classified correctly. Lotus root were classified correctly 57% of the time, maize were classified correctly 45% of the time and mung bean were classified correctly 64% of the time (MS *in prep*). It was also determined, that "the classification of the other types of granule, water chestnut, cassava, sweet potato and oats is poor with much confusion between these groups" (MS *in prep*). It was determined that the identification of a single starch granule is not very successful. Although there were only nine species of starch granules used in this experiment, many shared common characteristics and were easily mistaken for one another (MS *in prep*).

Future Research

If more individuals were examined, and more calculus samples were analyzed, it is possible that a more significant number of starch granules would be recovered. This would provide a better understanding of the dietary practices at Tarbat. In addition, with significantly more individuals being examined from both periods, it could be possible to see a difference in the dietary practices between the monastic and medieval populations. Additionally, it is imperative that a larger library of modern starch be created when determining plant species. It is could be possible that with a larger library available for comparisons, more conclusive identifications of ancient starch granules can be made.

As discussed in the previous chapter, there did seem to be a correlation between starch granule recovery and the lingual surfaces of the tooth. It would be interesting to explore this further by examining more individuals and comparing the number of starch granules discovered from either the buccal or lingual surfaces.

Final Thoughts

In order to get a better understanding of the dietary practices of any site, it is important to use several different avenues of information: the analysis of plant macrofossils, the identification of starch granules, stable isotope analysis, the examination of dental conditions and the examination of dental pathologies which relate to diet. Each of these fields of study provides a unique look at a specific area of the diet. A clear picture of the diet could not be seen without the information each of these areas provides. Although it was difficult to conclusively determine the diet at Tarbat, it is possible for a clear understanding of the dietary practices to be determined with the examination of more individuals, the recovery of a significant number of starch granules, and the comparison of this information with the stable isotope analysis and plant macrofossil identified from the site.