

# Infusion cuisine: a study of the value of foods in a pottery context across the transition to agriculture in the southern Baltic.

---

## **Volume I**

Total number of volumes 2

Hayley Saul  
Submission of thesis for PhD  
The University of York  
Department of Archaeology  
April 2011

## Abstract

Pottery residues offer a promising source of evidence about the types of food that were important in the Late Mesolithic and Early Neolithic, as domesticates began to be incorporated into culinary use. It is argued that although residues are not a *reflection* of the economy, there were diverse values to food that contributed to the sequence that domesticates appear in the archaeological record, as well as the seeming rate and extent to which they were adopted. Although calorific value has received attention (Rowley-Conwy 1984), and prestige models (Fischer 2002) acknowledge the social embeddedness of food culture, foods are also implicated in multiple evaluation processes that cross-cut the categories of ritual and mundane, prestige and subsistence. Ethnographic accounts suggest that food may be valued as perhaps medicine, for aesthetic purposes, for inducing altered consciousness, as well as negative values such as toxicity or pollution, to name a few. One way of understanding the concept of Cuisine is to suggest that it is a selective mixing and manipulation of these *values* into a cultural notion of food, rather than simply a literal mixing of food units into a meal, or menu. Such a concept of Cuisine is expressed in traditions of pottery use, through the choices of what it is acceptable to use certain vessels for. Investigating the values of food over time can suggest what motivations *brought about* a change in culinary practices to include domesticates.

This thesis reports on the results of multi-disciplinary analyses of pottery residues from sites in the southern Baltic. Lipid characterisation techniques and isotope analyses of absorbed residues and surface deposits were combined with novel plant microfossil investigations of starches from the surface ‘foodcrusts’, and stylistic information on the pots. An automated programme was developed to assign starches to a taxonomic class, based on comparison to modern reference examples according to 26 morphological variables. The combined findings suggest that foods were implicated in multiple processes of evaluation, not all of which directly motivated the change to a domesticated food economy.

# Table of contents

---

## Volume 1

Abstract.....	ii
List of contents.....	iii
List of figures.....	xiii
Acknowledgements.....	xxv
Author's declaration.....	xxvi

### **1. Introduction**

1.1. The necessity of studying cuisine and food values.....	1
1.2. Rationale for studying cuisine.....	2
1.3. Overview of the thesis.....	4

### **2. Background to the transition to agriculture**

2.1. Introduction.....	8
2.2. The Agricultural Package.....	11
2.3. Explanations for the transition to agriculture.....	12
2.3.1. 'Invasion' of the Nature-tamers.....	12
2.3.2. Population pressure: a game of sardines.....	21
2.3.3. Resource availability: cherry-picking species.....	24
2.3.4. Social change.....	30
2.4. Ideas of Cuisine.....	35
2.4.1. The front line of defence: cuisine as medicine.....	37
2.4.2. Cultivating a cautious palate: cuisine as poison.....	39

2.4.3. Cuisine through the looking-glass: edible Consciousness.....	41
2.4.4. Hampered food, or, cuisine as Gift.....	44
2.5. Value in archaeology.....	45
2.5.1. The Formalist-Substantivist debate in Economic Theory.....	47
2.5.2. Post-structuralism and the relationship between meaning and value...	49
2.5.3. <i>Reconstructing Value</i> .....	53
2.5.4. Concluding remarks on value and meaning.....	57
2.6. Research questions.....	59
2.7. Concluding ideas.....	59
<b>3. Background to the techniques</b>	
3.1. Introduction.....	62
3.2. Lipid residue analysis.....	63
3.2.1. Preservation.....	63
3.2.2. Contamination.....	66
3.2.3. Identification.....	66
3.2.4. Replication.....	76
3.3. Analysing plant microfossils.....	78
3.3.2. Starches.....	89
3.3.3. Calcium oxalate crystals.....	102
3.4. Conclusion.....	104
<b>4. Sample selection: sites and pottery</b>	
4.1. Ceramic typologies.....	107
4.1.1. Ertebølle vessels.....	107
4.1.2. Funnel Beaker types.....	108
4.1.2.1. Type 0.....	112
4.1.2.2. Type I.....	112
4.1.2.3. Type II.....	113

4.1.2.4. Type III.....	114
4.1.3. Type discrimination based on construction.....	114
4.2. The significance of sites selected for study.....	116
4.2.1. Neustadt.....	117
4.2.2. Wangels.....	118
4.2.2. Tybrind Vig.....	121
4.2.4. Åkonge.....	124
4.2.5. Stenø.....	126
4.2.6. The Bog Pots.....	127
4.3. Summary of the sampling strategy: sites, sherds and processes.....	129
<b>5. Material and methods</b>	
5.1. Introduction.....	132
5.2. Low powered microscopy.....	132
5.3. Lipid residue analysis.....	133
5.3.1. Modern reference material.....	133
5.4. Plant microfossils.....	134
5.4.1. Starch reference plants.....	134
5.4.2. Phytolith reference material.....	135
5.4.3. Experimental foodcrusts.....	136
5.4.4. Starch and phytolith extraction.....	137
5.4.5. Amylase degradation.....	138
5.4.6. Microscopy.....	138
5.4.7. Investigating contamination from the burial environment.....	138
5.4.8. Image acquisition for automated starch classification.....	141
5.4.9. Image analysis and starch classification.....	141
5.4.10. Phytolith classification.....	145
5.5. Experimental replication.....	146

5.6. Methodology development and evaluation.....	148
5.6.1. Results of automated starch classification: can these modern starches be identified to plant source?.....	148
5.6.2. Preliminary observations in the context of archaeological residues, and methodological adjustments.....	155
<b>6. Results</b>	
6.1. Introduction.....	158
6.2. Neustadt.....	158
6.2.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?.....	158
6.2.2. Are these indicators related to the vessel use or are they derived from the burial environment?.....	163
6.2.3. Can the microfossils be identified to a plant food origin?.....	165
6.2.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.....	170
6.2.5. Comparison of identified food contents to vessel feature.....	183
6.2.6. Summary of the Neustadt results.....	185
6.3. Åkonge .....	186
6.3.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?.....	186
6.3.2. Are these indicators related to the vessel use or are they derived from the burial environment?.....	189
6.3.3. Can the microfossils be identified to a plant food origin?.....	192
6.3.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.....	195
6.3.5. Comparison of identified food contents to vessel features.....	203
6.3.6. Summary of the Åkonge results.....	206
6.4. Wangels .....	207
6.4.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?.....	207

6.4.2. Are these indicators related to the vessel use or are they derived from the burial environment?.....	209
6.4.3. Can the microfossils be identified to a plant food origin?.....	210
6.4.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.....	211
6.4.5. Comparison of identified food contents to vessel features.....	216
6.4.6. Summary of the Wangels results.....	218
6.5. Tybrind Vig .....	219
6.5.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?.....	219
6.5.2. Are these indicators related to the vessel use or are they derived from the burial environment?.....	222
6.5.3. Can the microfossils be identified to a plant food origin?.....	225
6.5.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.....	228
6.5.5. Comparison of identified food contents to vessel features.....	235
6.5.6. Summary of the Tybrind Vig results.....	236
6.6. Stenø .....	237
6.6.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?.....	237
6.6.2. Are these indicators related to the vessel use or are they derived from the burial environment?.....	240
6.6.3. Can the microfossils be identified to a plant food origin?.....	241
6.6.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.....	244
6.6.5. Comparison of identified food contents to vessel features.....	250
6.6.6. Summary of the Stenø results.....	252
6.7. Bog Pots.....	253

6.7.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?.....	253
6.7.2. Are these indicators related to the vessel use or are they derived from the burial environment?.....	255
6.7.3. Can the microfossils be identified to a plant food origin?.....	257
6.7.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.....	259
6.7.5. Comparison of identified food contents to vessel features.....	261
6.7.6. Summary of the bog pot results.....	263

## **7. Discussion and interpretation**

7.1. Discussing culinary sub-themes.....	264
7.1.1. Are there regional cuisines, and do they change through time?.....	265
7.1.2. What is the relative importance of wild versus domesticated foods in the context of pottery?.....	270
7.1.3. What is the relative importance of plant versus animal foods in the context of pottery?.....	277
7.2. Interpretation: how is cuisine implicated in the transition to agriculture?..	280
7.2.1. Introduction.....	280
7.2.2. An ethnography of pottery values.....	282
7.2.2.1. The introduction of ceramics.....	282
7.2.2.2. A chaîne-opératoire of pottery production.....	284
7.2.3. Meeting the meat makers.....	291
7.2.3.1. Not for the cooking pot: animals as meat, animals as metaphor..	291
7.2.3.2. Fish for feasting? Responding to debates about fish in the Neolithic...	294
7.2.4. Weaning age and social structure: colloidal fascinations.....	295
7.2.4.1. Medicinal milk: a new weaning food?.....	295
7.2.4.2. Lactose as toxin: attitudes to milk processing.....	302
7.2.5. Plants.....	306
7.2.5.1. The relationship between plants and milk.....	307



7.2.5.2. Plants in pots and plants on settlements: the influence of management strategies on values.....308

7.2.5.3. Spice in hunter-gatherer cuisine.....311

## **8. Conclusions**

8.1. Summary of the argument.....315

8.1.1. How has food been valued in debates about domestication?.....315

8.1.2. *How* has this study altered appreciations of food value across the transition to agriculture?.....317

8.1.3. Summary of how cuisine is implicated in changes across the transition to agriculture.....318

8.2. Verification methods and future work.....321

8.2.1. Starch analyses.....321

8.2.2. Phytolith and calcium oxalate analyses.....322

**Bibliography**.....323

Volume 2: Appendices

### **Appendix I.**

A table showing the knowledge available to indicate the potential of phytolith production in northern European plant families, based on published material from other regions of the world. The table includes herbaceous angiosperms, trees, sedges and grasses.....2

Appendix II.

Standard Operating Procedures for lipid residue analysis.....6

Appendix III.

Descriptions of modern reference starches.....21

Appendix IV.

A table showing those plants with phytolith, calcium oxalate and starch content.....23

Appendix V.

Images of modern phytoliths, calcium oxalate crystals and starches.....25

Appendix VI.	
A full inventory of experimental cooking ceramics.....	36
Appendix VII.	
Starch and phytolith data per sherd, with lipid residue summaries.....	39
Appendix VIII.	
Cluster ‘D’ analysis dendrogram.....	250
Appendix IX.	
The Bodal K ceramic inventory.....	253



# List of figures

---

Figure 1. 1. A map of the sites from which ceramic and foodcrust samples were taken.

Figure 1.2. An example of a sherd from Neustadt with surface deposit or 'foodcrust' adherences.

Figure 2. 1. A map of southern Scandinavia showing all the key sites mentioned in this chapter.

Figure 2. 2. In the period around the transition to agriculture some new artefact forms emerge: a) new pottery styles, b) polished flint axes (<http://oltiden.natmus.dk>), c) shaft-hole axes, d) antler axes, e) megalithic monuments, f) megalithic monuments.

Figure 2. 3. A map adapted from Ammerman and Cavalli-Sforza (1971) illustrating the temporal thresholds envisaged for the Neolithic movement, in years BP.

Figure 2. 4. A pollen profile from the area of Fuglsø on Djursland, showing the reduction in elm around the Early Neolithic, and the coincident increase in birch, hazel, alder and oak (adapted from Andersen 1993, 88).

Figure 2. 5. The distribution of known timber-built graves from the Early Neolithic in Denmark (adapted from Madsen 1993, pg 96).

Figure 2. 6. The geographical distribution of Middle Atlantic pottery styles and the major strands envisaged as movement routes for domestication. Late Mesolithic Ertebølle pottery has been suggested as an innovation deriving from an eastern origin in Poland and Western Russia only recently (after Gronenborn 2003, pg 86).

Figure 2. 7. Ranges for securely dated early TRB pottery from southern Scandinavia suggest a rapid adoption. Data compiled from Fischer (2002) and Midgley (1992).

Figure 2. 8. The graph shows the complicated regressions and transgressions recorded as sea level curves from three sites. The green dashed line points to a coincident regression around 3100 uncalibrated bc (after Rowley-Conwy 1984, 315).

Figure 2. 9. Carbon isotopes indicate a marine-terrestrial distinction between samples of bone from Mesolithic and Neolithic contexts (after Richards *et al.* 2003a, 292).

Figure 2. 10. The Neolithic dolmen of Aldersro in the Åmosen, Zealand.

Figure 2. 11. The neighbouring graves at the site of Dragsholm, Zealand (Price *et al.* 2007, 194).

Figure 2. 12. Baltic amber and green olnet slate is exchanged easterly in the Mesolithic (Zvelebil 2006, 13).

Figure 2. 13. Top, Limnham greenstone axes have a westerly distribution compared to an easterly concentration of antler axes in eastern Zealand and south-western Sweden. Bottom, many sculpted bone artefacts have a westerly distribution.

Figure 3. 1. A graph showing the success rate for the recovery of lipid from ceramics in a preliminary study of Baltic pottery (Craig and Heron, 2006).

Figure 3. 2. The single compound isotope measurements from three British Neolithic sites, showing the high number of samples that fall in the range of ruminant dairy fats (Copley et al. 2005, 526).

Figure 3. 3. a) an SEM micrograph of dendriform phytoliths x5400 (Hayward and Perry 1980, 549), b) a light microscope image of grass silica skeletons. Emmer wheat (*T. dicoccum*). Bar is 20 microns (Rosen, 1992, 133).

Figure 3. 4. a) The long cell structure from emmer wheat closest to the rachis., b) the long cell structure from the middle portion of the emmer husk (Rosen, 1992, 135). Bar 20 microns.

Figure 3. 4. The process of elimination for distinguishing between the *Triticum* and *Hordeum* genus (after Ball et al., 1996).

Figure 3. 5. a) the thick long-cells of the middle portion of naked barley husk., b) the thin long-cells of the same species (Rosen, 1992, 138).

Figure 3. 6. a) *Triticum dicoccoides* showing surface craters, b) *Hordeum spontaneum* with lamellae and surface depressions specific to this species, c) *Aegilops genticulata* shows a central protruberance, d) *Aegilops peregrina* has visible lamellae. Scale bar 10µm (Piperno et al., 2004, 671).

Figure 3. 7. The molecular structure of a starch granule. Linear amylose interweaves with branching polymers of amylopectin. The branch-points equate with regions of greater crystallinity which radiate outwards from the hilum (Sajilata et al., 2006, 3).

Figure 3. 8. Starches of the *Triticum* genus. On the left healthy starches with defined characteristics and clear extinction cross. On the right cooked granules have a diffuse extinction cross (Henry et al., 2009, 918).

Figure 3. 9. Barley and wheat respond differently to varying processing activities (Henry et al., 2009, 919).

Figure 3. 10. The matrix shows the number of starches that were correctly classified by multivariate statistical analysis. In general the classifications are highly accurate (Torrence et al. 2004, 525).

Figure 3. 11. On the left elongated raphide calcium oxalate crystals in SEM. Right, prismatic styloids embedded in the cell wall in SEM (Franceschi and Nakata, 2005, 43).

Figure 4. 1. An Ertebølle pointed-based vessel with everted rim.

Figure 4. 2. a) An EBK pot with cylindrical profile, and b) an EBK pot with greater curvature and a more conical profile.

Figure 4. 3. A flat clay disc of the TRB period, with unknown function.

Figure 4. 4. An oval 'blubber' lamp from the EBK period, derived from Tybrind Vig.

Figure 4. 5. The typological scheme of C. J. Becker which separates vessel forms with functional discriminations.

Figure 4. 6. Type A funnel beakers (above) are one of the earliest Neolithic pottery examples in Becker's typological conception, and are associated with more closed forms (below) (Koch 1998, 404 & 437).

Figure 4. 7. The decorative motif common to the North Jutland Type C Funnel Beakers in Becker's sequence.

Figure 4. 8. (Top) A collared flask (Koch 1998, 540), (middle) a lugged vessel, (bottom) a funnel neck.

Figure 4. 9. A Type 0 Funnel Beaker with characteristic rounded base. This example is from Kongemosen 3 (Koch 1998, 485).

Figure 4. 10. A Type I vessel from Ejby Mose (Koch 1998, 417).

Figure 4. 11. A Type II vessel from Jordløse Mose XVII (Koch 1998, 517).

Figure 4. 12. A Type III vessel from Jordløse Mose XVIII (Koch 1998, 518).

Figure 4. 13. The three construction techniques used to create EBK and TRB ceramics, from left to right, H-construction, N-construction, U-construction.

Figure 4. 14. On undisputedly EBK vessels fingernails are visible in the coil surface, aiding the attachment of coils to one another.

Figure 4. 15. On undisputedly TRB vessels there is a change in the direction of the coil at the shoulder.

Figure 4. 15. A location map of Neustadt in Schleswig-Holstein, northern Germany, with a plan of the excavated portions of the site.

Figure 4. 17. Location of Wangels at the national and regional scale. The site is located on a former island in the middle of a now dry fjord. The regional map is taken from Grohmann 2004, 26.

Figure 4. 18. A map of the location of Tybrind Vig in Denmark, and at the outlet of a river at the regional scale.

Figure 4. 19. A location map of Åkonge in the wetland landscape of the Åmose.

Figure 4. 20. A plan of the bark floor at Akonge, found in proximity to abundant hazelnut shells on the dryland settlement.

Figure 4. 21. The location of the site of Målvegårds Mose in northern Zealand.

Figure 4. 22. The 'food culture model' of transforms that food undergoes from its production to the recovery by archaeologists.

Figure 5. 1. A table listing the modern plant reference species incorporated into the phytolith reference collection.

Figure 5. 2. The image on the left shows the cooking experiments in progress. The image on the right shows the resulting carbonised foodcrust in the base of a TRB replica vessel after cooking.

Figure 5. 3. Left, sherd 3020 from Neustadt showing the interior deposit (F). Right, the same sherd showing the exterior sooty deposit (S).

Figure 5.4. A) A partially gelatinised starch granule that is losing its molecular order, B) A swollen granule that has become brittle from the leaching of amylose, C) Modern maize (*Zea mays*) starches after a tannin soak showing evidence of staining.

Figure 5. 5. Objects automatically recognised by the programme could not be analysed if they were A) in contact with the edge of the image or, B) not starch granules.

Figure 5. 6. a) some granules are in clumps in which case shared boundaries are defined and replicated, b) the clumps can then be separated, c) where extraneous organic 'noise' was present grains were encircled making them easier to find.

Figure 5. 7. A table summarising the features of the granules measured in order to classify them (after Wilson *et al.* 2010).

Figure 5. 8. A table showing the main experiments carried out to replicate cooking of plant foods in ceramics.

Figure 5. 9. A table showing the modern plant references with their class number and details of the number of images, and granule number in training and test data sets.

Figure 5. 10. A table showing the percentage of granules from the training set (first column), that were correctly classified to the corresponding class in the rows.

Figure 5. 11. A table showing the percentage of correctly classified granules using a set of modern starches (test set) not used to train the programme.

Figure 5. 12. A table showing the number of modern reference images that were correctly classified and the number that weren't as well as an overall ranking of that class.

Figure 5. 13. On the left, an image of the degradation to einkorn (*Triticum monococcum*) A-type grains. In the middle and right, Type B grains are blackened in brightfield but retain an extinction cross in polarised light, all x600.

Figure 5. 14. Principal components analysis of the modern starch references shows that using the first two principal components there is some clustering in classes.

Figure 5. 15. Introducing the third principal component allows for the greater separation of overlapping classes, such as *Armoracia rusticana* (4) and *Sparganium erectum* (11).

Figure 5.16. Counts ( $\text{mg}^{-1}$ ) of interior (F) and exterior (S) starch granules for all the sites and residues investigated.

Figure 5.17. Counts ( $\text{mg}^{-1}$ ) of interior (F) and exterior (S) silica bodies for all the sites and residues investigated.

Figure 6. 1. The light brown feature in this image is a portion of fish scale with concentric circuli consistent with a member of the Salmonid family, x20.

Figure 6. 2. a) possible leaf matter x30, b) a possible plant stalk embedded in the charred matrix x30, c) bark periderm showing lenticels, x20.

Figure 6. 3. The amylase degradation of starches from a sub-group of Neustadt foodcrusts, showing also the positive presence of starches in the polarised negative controls and modern negative controls. All samples were viewed in both polarised and brightfield light. Polarised images were taken if starches were present because the extinction cross better demonstrates their occurrence.

Figure 6. 4. A time-lapsed capture of starch degradation with amylase from N\_2756\_F. The sequence from left to right documents intervals at 0 min, 3 min, 6 min, 12 min, x600. The method of capture and degradation in this instance follows Hardy *et al.* (2009).

Figure 6. 5. The morphological classes that were confirmed as starch by amylase degradation.

Figure 6. 6. Under the influence of heat bean-shaped starches swell (a-b), and may either begin to rupture as the gelatinisation point is reached (c), or they crack along lamellae (d).

Figure 6. 7. In a sample of 50 starches from a single 'bean-shaped' class at Neustadt, heat-induced swelling is in evidence. The shaded region illustrates the size range for modern unheated examples (N=50) of this class type. Outside this range, the granules began to show visible evidence of heat-alteration such as cracking.

Figure 6. 8. Starch counts from the Neustadt foodcrusts ( $\text{mg}^{-1}$ ). There is a nominal distinction between high and low counts, indicated by orange and green bars respectively.

Figure 6.9. Silica body counts for Neustadt foodcrusts ( $\text{mg}^{-1}$ ). Those bars indicated in green are statistically higher counts than those indicated by a blue bar.

Figure 6. 10. The automated classification of starch granules from Neustadt foodcrusts, showing the number of granules analysed for each sample with the percentage of granules allocated to each species class.

Figure 6. 11. Phytolith forms found in the Neustadt foodcrusts.

Figure 6. 12. The minimum, maximum and average size of globular sinuate phytoliths from archaeological samples, with modern *Alliaria petiolata* sizes for comparison.

Figure 6. 13. An SEM image of a probable globular sinuate phytolith from Neustadt (N\_2756\_F) indicated by the arrow.

Figure 6. 14. The bulk isotope values of the Neustadt foodcrusts showing EBK and TRB samples, arranged next to a graph with the same y-axis showing the number of starch granules  $\text{mg}^{-1}$ . Clusters are outlined.

Figure 6. 15. The bulk isotope ratios of archaeological samples plotted against modern experimentally cooked reference foods. This graph again compares the  $\delta^{15}\text{N}$  values to the starch counts  $\text{mg}^{-1}$ .

Figure 6. 16. Above, a graph plotting the single compound carbon isotope ratios on the C18:0 and C16:0 fatty acids. Below, a close-up on the ranges for ruminant adipose and dairy foods, with those samples in cluster A noted. Ranges were generated using authentic marine and freshwater reference fats from Danish coastal, river and lake waters. Terrestrial data are a combination of published references (Dudd and Evershed, 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

Figure 6. 17. Above, a graph showing the bulk isotope values for the Neustadt foodcrusts, overlaid with symbols that indicate whether significant quantities of silica bodies were associated with those samples. Below, the same plot of bulk isotope values, with symbols indicating whether there were significant starches associated with the sample.

Figure 6. 18. A plot of the bulk isotope ratios of the Neustadt foodcrusts. The datum points are overlaid with symbols representing the food class result of the sample acquired by GC-C-IRMS.

Figure 6. 19. The bulk isotope values of the Neustadt foodcrusts. Those samples with significant starch counts are represented by pie charts indicating the proportions of the different plant species identified using automated classification.



Figure 6. 20. The two graphs both show plots of the bulk isotope values for the Neustadt foodcrusts. In the above graph (a) EBK samples with significant starch are represented by a pie chart detailing the proportions of species represented. In the below graph (b) TRB samples with significant starch are represented by pie charts showing the proportions of plants cooked in them.

Figure 6. 21. A plot of the bulk isotope ratios of the Neustadt foodcrusts. Each datum point is represented by a symbol expressing the size of the vessel from which the sample was taken. Small= 5-15 cm, medium= 16-25 cm, large= 27-37 cm, extra large= >38cm.

Figure 6. 22. A plot of the bulk isotope values for the Neustadt foodcrusts. Each datum point is represented by a symbol that indicates the form type of the ceramic from which the sample derives.

Figure 6. 23. Examples of fish scales found in the Akonge foodcrusts that have concentric circuli patterning consistent with members of the Salmonid family, x40.

Figure 6. 24. A possible fragment of eel (*Anguilla anguilla*) scale recovered from Akonge foodcrust KML 49.5/77.5:80\_F, x40.

Figure 6. 25. The graph shows the length and width measurements taken of a random selection of a single class of 'bean-shaped' starch granules to suggest the degree of granule swelling caused by cooking at Åkonge. Modern size ranges for the same class (N=50) are indicated by the shaded region.

Figure 6. 26. Amylase degradation of starch granules from a sub-group of the Akonge foodcrusts, showing the presence of starch in samples with negative amylase, and the absence in samples positive for amylase.

Figure 6. 27. A graph showing the normalised count of starches ( $\text{mg}^{-1}$ ) for each foodcrust sample from Åkonge. Those bars in orange indicate samples with high counts  $\text{mg}^{-1}$ , those with green bars are low counts  $\text{mg}^{-1}$ .

Figure 6. 28. A graph showing the number of silica bodies ( $\text{mg}^{-1}$ ) for each of the Åkonge foodcrusts. Those with a green bar indicate samples with high counts  $\text{mg}^{-1}$ , whilst those with a blue bar indicate samples with low counts  $\text{mg}^{-1}$ .

Figure 6. 29. A table of the number of granules submitted for automated classification, with percentages of each species identified in the foodcrusts.

Figure 6. 30. The findings of phytolith types in the Åkonge foodcrusts.

Figure 6. 31. A plot of the bulk carbon and nitrogen isotope values for the Åkonge foodcrusts, with isotope ratios for modern reference foods.

Figure 6.32. a) A plot of the bulk carbon and nitrogen isotope ratios of the Åkonge foodcrusts, with symbols indicating samples where the presence of starches was greater than  $100 \text{ mg}^{-1}$ , b) A plot of the bulk isotope ratios of the Åkonge foodcrusts with symbols indicating samples where silica body counts were greater than  $20 \text{ mg}^{-1}$ .

Figure 6. 33. The  $\delta^{13}\text{C}$  carbon isotope ratios of C16:0 and C18:0 fatty acids from the absorbed lipid component of the Åkonge ceramic samples. Mesolithic EBK samples are indicated with green symbols, Neolithic TRB samples are indicated with red symbols. Ranges were generated using authentic marine and freshwater reference fats from Danish waters. Terrestrial data are a combination of published references (Dudd and Evershed, 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

Figure 6.34. A plot of the bulk carbon and nitrogen isotope ratios of the Åkonge foodcrusts. Each datum point has been given a symbol indicating the food class defined by single compound isotope analysis for the absorbed lipid of the corresponding sherd.

Figure 6.35. A graph plotting the bulk carbon and nitrogen isotope ratios of the Åkonge foodcrusts. Each datum point with significant starch counts is indicated with a pie chart illustrating the proportions of each plant type found as a result of automated classification of the starches.

Figure 6.36. a) The top graph is a plot of the bulk carbon and nitrogen isotope values for the Åkonge foodcrusts with EBK samples that contain significant starches indicated by pie charts showing the proportion of different plants in those samples., b) The same graph of bulk isotope data, but with TRB samples with significant starches indicated by pie charts showing the proportion of different plants.

Figure 6.37. A graph showing the bulk carbon and nitrogen isotope values of the Åkonge foodcrusts with each datum point represented by a size of vessel classifier. Small= 5-15 cm, medium= 16-26 cm, large= 27-37 cm, extra large= >38 cm.

Figure 6.38. A graph plotting the bulk carbon and nitrogen isotope values of the Åkonge foodcrusts. Each datum point is represented by a symbol that defines the type of vessel the sample came from.

Figure 6.39. A graph plotting the bulk carbon and nitrogen isotope values of the Åkonge foodcrusts. Each datum point is represented by a symbol that indicates the width of the vessel wall that respective samples came from.

Figure 6.40. An image showing the characteristically amorphous, charred nature of the Wangels foodcrusts, x20.

Figure 6.41. The amylase degradation of Wangels sample KE\_34\_F. With the negative addition of amylase starches are abundant in both the archaeological and modern control. When amylase was added degradation occurred in both the modern and archaeological samples.

Figure 6.42. A graph showing the counts  $\text{mg}^{-1}$  of starches in the Wangels foodcrusts. Only sample KE\_34\_F measures high counts (orange bars), the other foodcrusts exhibit low granule counts (green bars).

Figure 6.43. A graph showing the silica body counts  $\text{mg}^{-1}$  for the Wangels surface deposits. Blue bars indicate that all of the samples were low in phytoliths.

Figure 6.44. A table showing the automated classification of the Wangels foodcrust with a provisionally high count. The proportion of each plant present in the sample is indicated beneath the plant name.

Figure 6.45. A graph of the bulk carbon and nitrogen isotope values of the Wangels foodcrusts, showing also the values for modern reference foods.

Figure 6.46. A graph plotting the  $\delta^{13}\text{C}$  values of C16:0 and C18:0 compounds from absorbed lipid in the Wangels sherds. Those samples with corresponding foodcrusts are annotated. All the samples are from Funnel Beaker style vessels and so are indicated with a red symbol. Ranges were generated using authentic marine and freshwater reference fats from Danish coastal and lake waters. Terrestrial data are a combination of published references (Dudd and Evershed 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

Figure 6.47. A graph plotting the bulk carbon and nitrogen isotope values for the Wangels foodcrusts. Each datum point is represented by a symbol that matches the class of food defined by single compound isotope analysis of the corresponding sherd fabric.

Figure 6.48. A pie chart illustrating the proportions of plants defined by automated starch classification for the only Wangels foodcrust with high starch counts  $\text{mg}^{-1}$ .

Figure 6.49. A graph plotting the bulk carbon and nitrogen isotope values of the Wangels foodcrusts. Each datum point is represented by a symbol detailing the size of the vessel from which the sample derives. Diameter sizes: small= 5-15 cm, medium= 16-26 cm, large= 27-37 cm, extra large= >38 cm.

Figure 6.50. A graph plotting the bulk nitrogen and carbon isotope ratios for the Wangels foodcrusts. Each datum point is represented by a symbol indicating the type of funnel vessel the sample came from.

Figure 6.51. a) A possible fragment of eel scale, x30, b) a cycloid fish scale, almost complete, x10, c) a fragment of possible bone showing a longitudinal structure, x20.

Figure 6.52. A graph showing the length and width measurements ( $\mu\text{m}$ ) for 100 randomly chosen starch granules of the same 'bean-shaped' class, showing the swelling alteration caused by heat. The shaded region of the graph shows the size range for modern unheated granules of this class.

Figure 6.53. The  $\alpha$ -amylase degradation of starches from four of the Tybrind Vig foodcrusts.

Figure 6.54. A graph of the starch counts  $\text{mg}^{-1}$  for the Tybrind Vig foodcrusts. High counts are indicated by samples with an orange bar, whilst low counts are indicated by a green bar.

Figure 6.55. A graph of silica body counts  $\text{mg}^{-1}$  for the Tybrind Vig foodcrusts. Those samples with a green bar indicate samples that are considered to have been used to process silica rich plants.

Figure 6.56. A table of the automated starch classification results from Tybrind Vig. The proportion of each plant represented in the starch results is given beneath the respective species'.

Figure 6.57. The types of phytoliths found in the Tybrind Vig foodcrusts.

Figure 6.58. A graph plotting the bulk carbon and nitrogen isotope ratios of the Tybrind Vig foodcrusts, also showing the values for modern reference foods.

Figure 6.59. A graph plotting the  $\delta^{13}\text{C}$  isotope values for C16:0 and C18:0 fatty acids from the lipid absorbed into the Tybrind Vig vessels. Ranges were generated using authentic marine and freshwater reference fats from Danish waters. Terrestrial data are a combination of published references (Dudd and Evershed 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals. Figure 6.60. A graph plotting the bulk carbon and nitrogen isotope ratios of the Tybrind Vig foodcrusts. Each datum point is represented by a symbol indicating the food class defined by single compound isotope analysis of the corresponding sherd.

Figure 6.61. A graph plotting the bulk carbon and nitrogen isotope values for the Tybrind Vig foodcrusts. Each datum point is represented by a symbol that indicates the number of aquatic biomarkers present from absorbed and surface deposits, based on GC-MS results.

Figure 6.62. A graph plotting the bulk carbon and nitrogen isotope values of the Tybrind Vig foodcrusts. Those samples that have significant starch counts are represented by pie charts

illustrating the proportions of different plants present based on automated starch classification.

Figure 6.63. A graph plotting the carbon and nitrogen isotope values for the Tybrind Vig foodcrusts. Each datum point is represented by a symbol indicating the stratum from which the sample derives.

Figure 6.64. The two images on the left display carbonised Salmonid fish scales, and the image on the right is a piece of possible bone or fish scale.

Figure 6.65. A graph showing the length and width measurements ( $\mu\text{m}$ ) for 50 randomly chosen starch granules of the same 'bean-shaped' class, showing the swelling caused by heat. The shaded region of the graph shows the size range for modern unheated granules of this class.

Figure 6.66. The  $\alpha$ -amylase degradation of starches from two of the Stenø foodcrusts.

Figure 6.67. A graph of the starch counts  $\text{mg}^{-1}$  for the Stenø foodcrusts. High counts are indicated by samples with an orange bar, whilst low counts are indicated by a green bar. Bars with question marks indicate samples provisionally accepted for starch classification.

Figure 6.68. A graph of the silica body count  $\text{mg}^{-1}$  for the Stenø foodcrusts. Those samples with a green bar indicate samples that are considered to have been used to process silica rich plants.

Figure 6.69. A table of the automated starch classification results from Stenø. The proportion of each plant represented in the starch results is given beneath the respective species.

Figure 6.70. The types of phytoliths found in the Stenø foodcrusts.

Figure 6.71. Scanning Electron Microscope images of a suspected *Alliaria petiolata* phytolith embedded in the carbonised matrix.

Figure 6.72. A graph plotting the bulk carbon and nitrogen isotope values of the Stenø foodcrusts, also showing the values for modern reference foods.

Figure 6.73. a) A plot of the bulk isotope values for Stenø overlaid with samples with high starch counts  $\text{mg}^{-1}$ , b) The same plot of bulk isotope values but overlaid with samples high in silica bodies  $\text{mg}^{-1}$ .

Figure 6.74. A graph plotting the  $\delta^{13}\text{C}$  isotope values from C16:0 and C18:0 fatty acids from the lipid absorbed into the Stenø vessels.

Figure 6.75. A graph plotting the bulk carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is represented by a symbol that indicates the corresponding single compound isotope food class that is defined for the sherd.

Figure 6.76. A graph plotting the bulk carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is represented by a symbol that indicates the number of aquatic biomarkers present from absorbed and surface deposits, based on lipid characterisations.

Figure 6.77. A graph plotting the bulk carbon and nitrogen isotope values of the Stenø foodcrusts. Those samples that have significant starch counts are represented by pie charts illustrating the proportions of different plants classified by automated starch identification.

Figure 6.78. A graph plotting the carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is indicated by a symbol representing the size of the vessel

from which the sample derives. Diameter sizes: small= 5-15 cm, medium= 16-26 cm, large= 27-37 cm, extra large= >38 cm.

Figure 6.79. A graph plotting the bulk carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is represented by a symbol indicating the type of vessel from which the sample derives.

Figure 6.80. a) a fragment of a possible Salmonid fish scale, b) an artefact with a longitudinal structure, possibly bone.

Figure 6.81. A brightfield and polarised image of starches from foodcrust sample NMA\_40882 showing an absence of cracking and heat alteration, and a sharp extinction cross indicating maintained molecular order of the granule. Mag x600.

Figure 6.82. The  $\alpha$ -amylase degradation of starches from three of the Bog Pot foodcrusts.

Figure 6.83. A graph of the starch counts  $\text{mg}^{-1}$  for the Bog Pot foodcrusts. Samples with orange bars (and question marks) indicate samples provisionally accepted for automated classification despite not being statistically different from exterior  $_S$  deposits.

Figure 6.84. A graph of silica body counts  $\text{mg}^{-1}$  for the Bog Pot foodcrusts. Those samples with a green bar indicate samples considered to have been used to process silica rich plants.

Figure 6.85. A table of the automated starch classification results from the Bog Pots. The proportion of each plant represented in the starch results is given beneath the respective species.

Figure 6.86. The types of phytoliths found in the Bog Pot foodcrusts.

Figure 6.87. A graph plotting the bulk carbon and nitrogen isotope values of the Bog Pot foodcrusts, also showing comparison values for modern reference foods.

Figure 6.88. A graph plotting the bulk carbon and nitrogen isotope values of the Bog Pot foodcrusts. Those samples with significant starch counts are represented by pie charts illustrating the proportions of different plants identified by automated starch classification.

Figure 6.89. A plot of the bulk carbon and nitrogen isotope values for the Bog Pot foodcrusts. Each datum point is represented by a symbol indicating the type of vessel the sample comes from.

Figure 6.90. A plot of the bulk carbon and nitrogen isotope values for the Bog Pot foodcrusts. Each datum point is represented by a symbol indicating the form of vessel the sample came from.

Figure 7.1. A plot of the collated bulk carbon and nitrogen isotope values for all the sites, indicating samples from inland and coastal locations.

Figure 7.2. Single compound isotope values for a) coastal, and b) inland sites. Including values for Roskilde Fjord, Bjørnsholm, Norsminde, Store Åmose and Ringkloster. Red datum points indicate TRB samples, green datum points indicate EBK samples. The line indicates a theoretical mixing curve calculated by weight, so a 75% marine mammal to 25% dairy mixture will be weighted outside the modern range for marine foods, for example.

Figure 7.3. A series of pie charts collating the results of automated starch classification for inland and coastal sites, incorporating a breakdown of these regional plant traditions into EBK and TRB periods.

Figure 7.4. Bulk carbon and nitrogen isotope values for all the sites studied showing distributions of EBK and TRB samples. Modern reference foods are included.

Figure 7.5. The single compound isotope values for all the sites collated. Extra samples from Roskilde Fjord, Bjørnsholm, Ringkloster, Store Åmose and Norsminde are included. Red datum points indicate TRB samples, green datum points indicate EBK samples. The line indicates a theoretical mixing curve calculated by weight, so a 75% marine mammal to 25% dairy mixture will be weighted outside the modern range for marine foods, for example.

Figure 7.6. The results of automated starch classification on a site by site basis, with arrows indicating the time period over which each pie chart of plant use tradition spans.

Figure 7.7. A summary map showing the wider evidence for early cereal introductions in each region of the study area. Red indicates direct evidence of grains, green indicates pollen evidence of cereals, blue indicates grain impressions in pottery.

Figure 7.8. A summary map of the wider evidence of early domesticated animals. The map at the bottom is a close up of the Åmosen where a particularly high concentration of sites have been discovered with early domesticates.

Figure 7.9. A graph showing the total number of sherds with evidence of each class of food from single compound analyses, lipid characterisation and plant microfossils. Extra samples from Roskilde Fjord, Store Åmose, Ringkloster, Bjørnsholm and Norsminde are not included because there are no plant microfossil data from these sites.

Figure 7.10. A table showing the relative calorific values of different food classes for a medium-sized vessel.

Figure 7. 11. Section through the midden at Ertebølle, showing the layers of shell-ash that begin in the a-ceramic period.

Figure 7. 12. A chaîne-opératoire of pottery manufacture for Ertebolle-style vessels, which is similar in many ways to the Funnel Beaker chaîne-opératoire.

Figure 7. 13. Greater challenges to construction are posed by vessels with curved contours (a), than more straight-sided conical pots (b). Both examples are from Tybrind Vig.

Figure 7. 14. Examples of 'teethed' orifices on Ertebølle pottery vessels from (a-c) Bodal K, Åmosen, d-e) examples from Åkonge, Åmosen, f) an example from Neustadt, Schleswig-Holstein.

Figure 7. 15. Pre-fired clay is grey but transforms to an oxidised red with firing. The process of construction embodies a management of material transformation.

Figure 7.16. An example of a very thin-walled pot from Bodal K, Åmosen. The N-construction is very oblique suggesting the paddle-and-anvil technique was used.

Figure 7.17. The relative proportions of classes of foods in pottery, compared to proportions of those classes in bone assemblages at Neustadt.

Figure 7. 18. The relative proportions of classes of foods in pottery, compared to proportions of those classes in bone assemblages at Wangels.

Figure 7.19. A pie chart showing the relative proportions of the fish bones from Neustadt (Glykou 2010).

Figure 7.20. A five-year-old at Nivågård on Zealand was buried with its head resting on a stone pillow (Jensen and Hansen, 1999, 15).

Figure 7.21. a) The collective burial at Strøby Egede comprised eight individuals, five of which are child burials, b) the burial of an adult and child at Tybrind Vig.

Figure 7. 22. A chart showing the ages of dietary stress shown on tooth enamel at the Skateholm cemeteries. At Skateholm II the weaning period is singular c.5years old, but several periods of dietary stress possibly linked to multiple weaning stages are in evidence at Skateholm I.

Figure 7. 23. A table showing the antibiotic constituents of different types of milk.

Figure 7. 24. A wooden spoon from the Danish National Museum collection. The spoon is from Maglelyng in the Åmosen.

Figure 7. 25. A table showing the lactose content of different milk derivatives.

Figure 7. 26. Vessel N\_22, a funnel bowl that would have had an open orifice suitable for separating cream, or whey from milk solids. Picture by K. Glykou. Scale 3:4.

Figure 7. 27. A table showing the 'weed-species' introduced with the earliest advent of cereals in southern Scandinavia, with documented instances where these plants exhibit spice-properties. O= a minor presence, X= a considerable presence, XX= a major presence. Adapted from Regnell and Sjogren (2006c, 150-151), with additions from Watts (2007), Facciola (1998), and Bown (1995).

## Acknowledgements



*In memory of Eva Koch*

My final task- apart from wiping the disbelieving look that three years can pass so quickly- is to muster some sort of linearity to my scattered memories and pay my respect and gratitude to all those that have helped and encourage me on the way. Here goes:

I must begin by thanking my supervisors Oliver Craig and Carl Heron, not only for the opportunity to do a PhD in the first place, but for all their efforts on my behalf, for teaching me ‘new things’ (my favourite subject), and for making the experience so action-packed with laughter. I’ve really enjoyed working with you both, and learning from you too. Thanks to Val Steele for working so hard to produce data for the project, like an oasis of calm! You’ve always been at the other end of an email with help and advice, and I’m really grateful.

Thanks also to all the project collaborators; I’ve really valued the time we’ve spent together sampling, digging, and chatting. Anders Fischer, for giving so much of your time and helping me get to grips with pottery, and for giving the project access to the Åkonger and Stenø material so freely. Thanks to Sönke Hartz, Katerina Glykou and Harald Lübke for kind permission to use the Neustadt and Wangels material. It’s been great to work with you all, and thank you for making us so welcome in Schleswig. Søren Andersen, thank you for allowing us to use the material from Tybrind Vig, and for letting me excavate at the Havnø shell midden. Thanks to Niels Wickman and everyone at Holbæk Museum for allowing me to study the Stenø pottery, making me feel so welcome, and taking me on exploratory fieldtrips to the monuments on northern Zealand. Thank you to Sorø Museum for allowing me to study the Bodal K pottery. Also, to all at Kalundborg Museum for allowing me access to study the Åkonger pottery. Also thanks to Poul Otto Nielsen for allowing the project to drill into the Danish National Museum’s beautiful ‘bog pots’. A special thank you must go to Eva Koch who sadly died whilst the project was underway. Thanks for everything Eva; for all your encouragement and contagious enthusiasm, your time and efforts even when you were ill.

Thanks to the scientific advisors that have contributed their time and knowledge: Geoff Bailey, Nicky Milner, Julie Wilson, Karen Hardy, Allan Hall, Marco Madella.



Your expertise has been invaluable. Special thanks to Nicky for patiently keeping me sane, above and beyond the duty of her official role as supreme high commander of the thesis advisory panel. Also to Marco Madella whom I've pestered with images of microfossils whilst he has been in every far-flung corner of the known world, thank you. Julie, I'm really glad to have had the opportunity of working with you, thanks for your efforts on my behalf. Thanks to Rick Allen for support, for keeping me on the straight and narrow of health-and-safety protocols, and for great advice including, 'don't drink those acorn tannins'. Thanks also to Cynthia Spiteri for running some of our experimental pots on the GC, and for teaching me to do the extraction. Also thanks to The Royal Botanical Gardens at Kew for providing some of the modern starch reference material, greatly appreciated.

I owe such a great debt of gratitude to my friends and family for supporting me over the last three years (+/-6 years build up). You're all great, and hilarious, and valued. So, Mum, Dad, Em, Mark, Ariane, Granny Shop, Grandad Shop, Granny Seaside, Grandad Seaside, James, Leslie, Aleks, Steve, Nicky, Jon, Timur, Emma W, Andi, Irene, everyone in S Block and King's Manor- thanks!

### **Author's declaration**

Lipid residue analyses were carried out by Dr. Val Steele at the University of Bradford. Pottery analysis of Wangels and Neustadt was provided by Katerina Glykou. Pottery analyses of the National Museum bog pots were carried out by Dr. Eva Koch of that institution. The automated starch classification programme was collaboratively produced with Dr. Julie Wilson, University of York.







