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NEW FOOD IN OLD POTS – CHARRED ORGANIC RESIDUES IN EARLY NEOLITHIC CERAMIC VESSELS FROM SWIFTERBANT, THE NETHERLANDS (4300-4000 CAL BC)

The introduction of pottery production in the Early Neolithic has facilitated the archaeological study of many aspects of society. Ceramics are frequently used to define archaeological cultures, and due to their relatively swift stylistic and/or technological development they allow for relatively detailed phasing. However, ceramic vessels are also tools bearing traces of their actual use in everyday prehistoric life. Thanks to the developments in the field of organic residue analysis it has become possible to study these traces in order to identify the actual use of pots (Heron / Evershed 1993; Oudemans / Boon 1996; Evershed et al. 1999; Saul et al. 2012). In this contribution organic residue analysis is applied in order to determine whether different groups of pots from one site may have had different functions. An approach is chosen that combines botanical analysis by means of scanning electron microscope (SEM) with chemical residue analysis using direct temperature-resolved mass spectrometry (DTMS) in order to ascertain the original contents of vessels from both proposed subgroups. The use of this combined botanical and chemical approach makes it possible to identify micro-fragments of the (partially) charred processed foods as well as to determine the overall chemical composition of the foods prepared in the vessel (Kubiak-Martens 2006; Oudemans / Eijkel / Boon 2007; Oudemans / Kubiak-Martens 2012).

The ceramics studied here derive from the type site of the Swifterbant culture, Swifterbant S3 (prov. Flevoland/NL). The Swifterbant culture is a Late Mesolithic and Early Neolithic group of which remains are found in the wetlands between Antwerp (Belgium) and the Dümmer (Lower Saxony). The archaeological sites are as a rule embedded in Holocene sediments which allows a fine-grained narrative of piecemeal

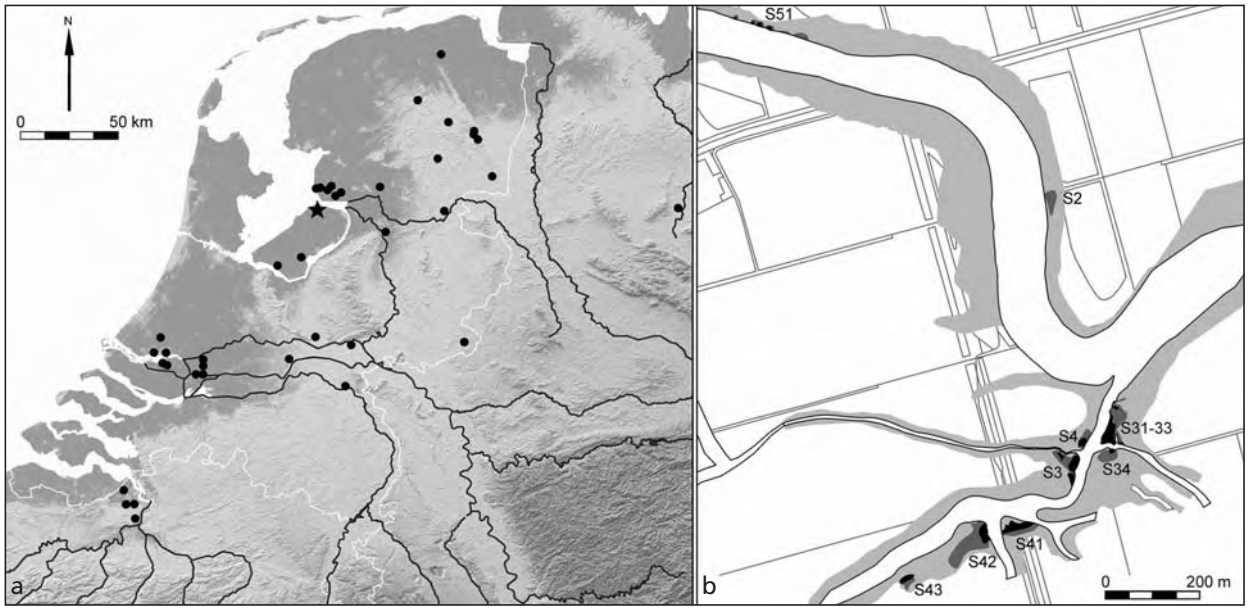

Fig. 1 The Swifterbant sites: **a** distribution of sites of the Swifterbant culture. The type site is indicated with a star (based on Louwe Kooijmans 2007, fig. 27, 4). – **b** the Swifterbant creek system with archaeological sites (based on Deckers 1979, fig. 1).

S2	sherds (n)	average wall thickness (mm)	wall decoration (%)	rim decoration (%)
plant	153	9.3	7	37
plant and stone grit	129	9.2	7	30
stone grit	72	9	1.5	43
S3	**sherds (n)**	**average wall thickness (mm)**	**decorated (%)**	**decorated (%)**
plant	259	10.5	10	48
plant and stone grit	110	9.9	12	79
stone grit	20	9.7	6	100
S4	**sherds (n)**	**average wall thickness (mm)**	**decorated (%)**	**decorated (%)**
plant	96	11.1	6	23
plant and stone grit	1105	10.9	2	24
stone grit	367	10.1	3	55

Tab. 1 Sherd characteristics of the sites Swifterbant S2, S3 and S4.

incorporation of ceramics (from c. 5000 cal BC), domestic animals (from c. 4700 cal BC) and cereals (from c. 4300 cal BC; Raemaekers 1999; Raemaekers 2003).

The site S3 is located in Swifterbant along a creek system, which holds several more archaeological places (**fig. 1**). Several dozen ^{14}C dates from the sites indicate that the occupation falls within the period 4300-4000 cal BC (Peeters 2007, 339). The plateau in the calibration curves prevents a more precise dating, but the occurrence of several fits of stone artefacts between the locations (Devriendt 2013) suggests that they are contemporaneous. Thanks to the wetland environment in which the sites have been preserved, there is detailed knowledge of many aspects of the occupation. The subsistence evidence is relevant to understand what type of food may have been processed in the pots. The zoological analysis (Zeiler 1997, tab. 3) indicates that pigs were of primary importance (57.4 % in bone numbers), including both domestic pigs and wild boar. Domestic cattle (8.6 %) and sheep/goat (0.2 %) are present as well. Major wild species are otter (13.7 %) and beaver (13.2 %). Apart from mammals, both birds and fish are well represented in bone remains. The botanical analysis reveals a similar hybrid character with the use of both cereals (naked barley [*Hordeum vulgare*] and emmer wheat [*Triticum turgidum* ssp. *dicoccum*]) and wild plants such as hazelnuts, apples and berries (van Zeist / Palfenier-Vegter 1984; Cappers / Raemaekers 2008, tab. 1). The subsistence strategy of these people may be termed »extended broad spectrum economy« (Louwe Kooijmans 1993), in which risk control by means of diversification seems essential (Cappers / Raemaekers 2008).

Until now, the ceramics from the Neolithic sites near Swifterbant c. 4300-4000 cal BC have been considered functionally homogeneous. Due to the frequent occurrence of food crusts and the strict decorative schemes, there was no inclination to consider the presence of functionally defined subgroups (Raemaekers 1999, 30-35; de Roever 2004, 50-52). A new ceramic analysis of three contemporaneous Swifterbant sites suggests that two subgroups may be identified by a correlation between temper, wall thickness and decoration.

SWIFTERBANT CERAMICS

The excavations at the Swifterbant creek banks have been carried out at three sites. It concerns S2 located along the main stream, and the neighbouring sites S3 and S4 along a smaller stream (**fig. 1**). The ceramics have been studied extensively by de Roever (1979; 2004). In addition, random samples from S2 and S3 (Raemaekers 1999, 30-35) and the complete assemblage from S4 were analysed. A study on the correlation of various aspects of the sherd assemblages made clear that three technological variables are related. Correlations can be observed between wall thickness, decoration and temper (**tab. 1**):

1. There is a correlation between temper and average wall thickness. In all three sites the sherds tempered with plant material are on average thicker than those which combine plant and grit temper, while sherds with only grit temper are on average the thinnest. It is noteworthy that the absolute numbers differ between the sites.
2. There is a correlation between temper and the frequency of wall decoration. Again, the absolute numbers differ between the sites. Wall decoration is more frequent on sherds with only plant temper, than with only grit temper. Sherds with plant and grit temper have similar frequencies as those with plant temper only (S2, S3) or with grit temper only (S4).
3. There is a correlation between temper and the frequency of rim decoration. On all three sites, sherds with grit temper only are more often decorated on the rim, while the lowest frequencies are seen on those with plant temper only. Sherds with a combination of plant and grit temper have somewhat varying frequencies.

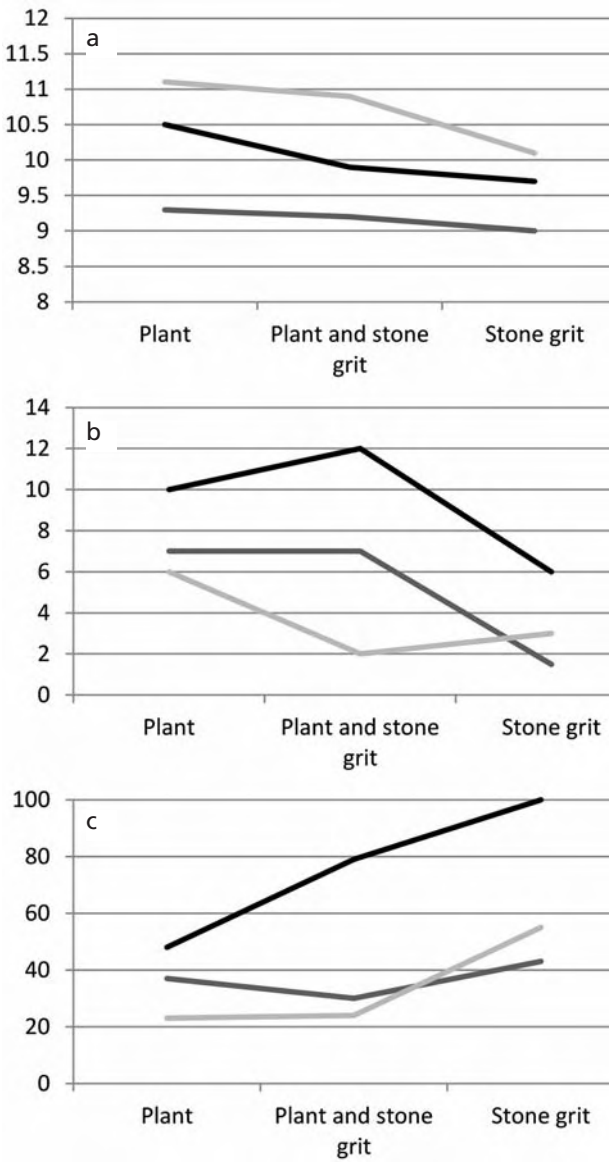

Fig. 2 Visual presentation of observed correlations between temper and average wall thickness (**a**), wall decoration percentage (**b**) and rim decoration percentage (**c**). – ▬ S2; ▬ S3; ▬ S4. – (Illustration D. C. M. Raemaekers).

In themselves, these correlations are not very strong, and it is obvious that there are no clear-cut subgroups defined on the basis of the variables mentioned. However, the fact that the correlations are the same for all three sites studied (fig. 2) suggests that these are not accidental patterns, but indications for meaningful subgroups of pottery. The subgroups were obviously reproduced at the three sites throughout the lifespan of their occupation.

To study a potential differentiation in vessel use between these two subgroups of pottery, the largest assemblage, S3, was sampled for a detailed analysis of organic residues. All larger pot fragments with visible surface residues were selected to allow an analysis in which the SEM and DTMS results could be compared not only to sherd characteristics – such as temper, wall thickness and decoration – but also to vessel characteristics such as pot size or form. A total of 32 pots were selected (fig. 3). Four vessels (nos 21, 25, 27 and 30) are later excluded due to the lack of reconstructable vessel profiles, while three vessels (nos 12, 16 and 18) are left out of consideration due to the recently proposed possible younger age (see Raemaekers 2011). Two pots not only contain plant and stone grit temper, but also some grog. These vessels are considered to belong to the same category as those with only plant and stone grit temper. The relevant characteristics are presented in table 2. A total of 25 residues are analysed, a number considered representative (37 %) of the total number of 67 residues observed in the S3 ceramics by de Roever (2004, 173-183).

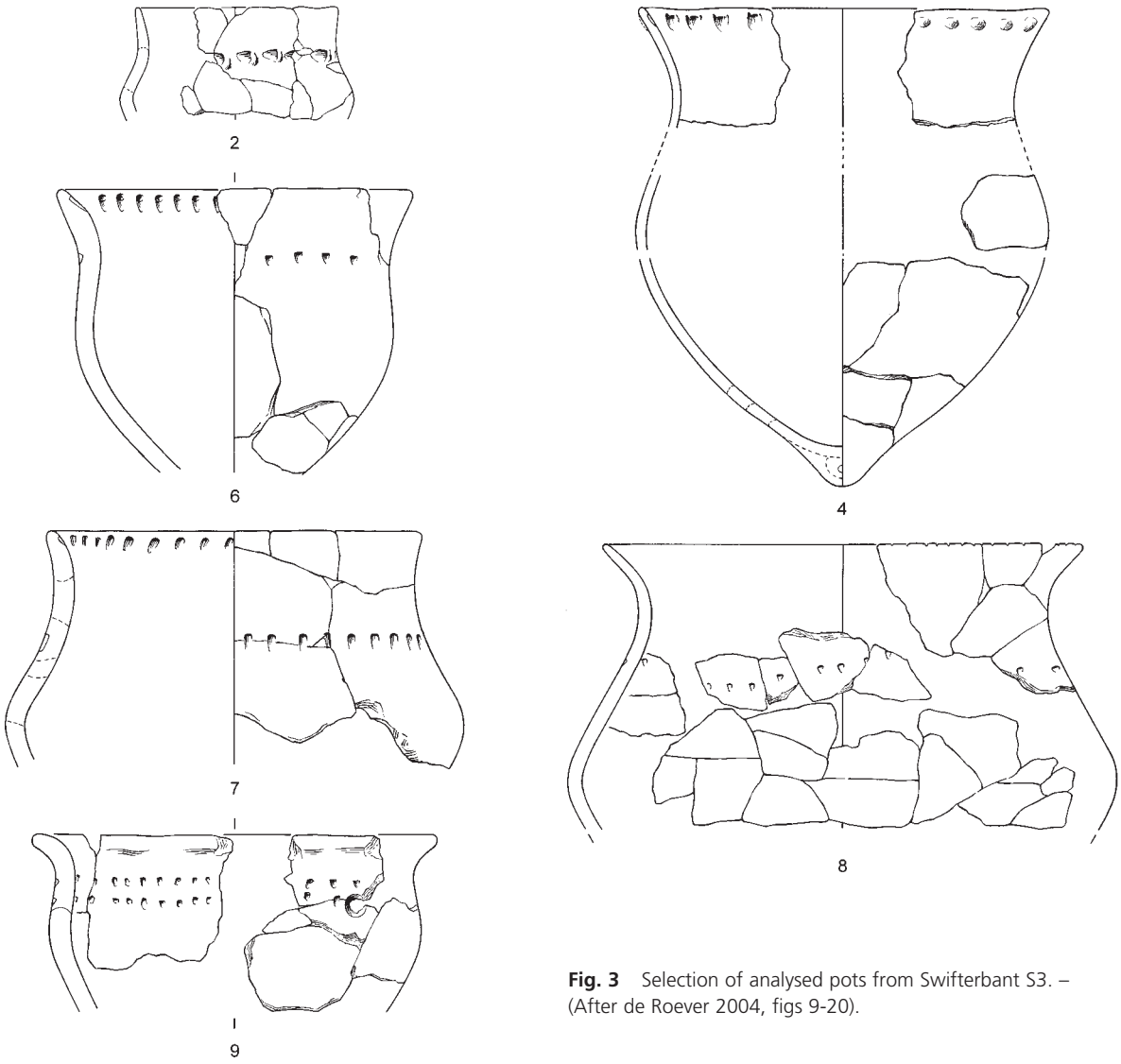

Fig. 3 Selection of analysed pots from Swifterbant S3. – (After de Roever 2004, figs 9-20).

BOTANICAL RESIDUE ANALYSIS

Methods: scanning electron microscope (SEM) examination

The identification of morphological characteristics of charred remains of processed plant food such as residues encrusted on ceramic vessels requires the use of a SEM. It provides an opportunity to study both micro-morphological and anatomical features of very small fragments of plant tissues that occasionally survive the process of food preparation and subsequent cooking (Kubiak-Martens 2006; Kubiak-Martens 2008; Kubiak-Martens / Oudemans 2008; Oudemans / Kubiak-Martens 2012). The examinations were carried out at the SEM laboratory at the Naturalis Biodiversity Center in Leiden. Specimens of selected organic residues were first detached from the sherds and then mounted on SEM stubs using double-sided carbon tape strips. They were then gold-coated and examined using a JOEL JSM-5300 scanning electron microscope at magnifications of 100x to 3500x. For reliability, several areas of different specimens from each organic residue were analysed.

pot	figure de Roever 2004	temper	wall thickness (mm)	rim decoration			wall decoration	rim diameter (cm)	wall diameter (cm)	generalised diameter (cm)
				inside	top	outside				
1	10d	plant	7	–	–	–	+	11	13	12
2	–	plant	7	–	–	–	+	11	13	12
3	11b	plant and stone grit	7	+	–	–	–	23	26	25
4	11c	plant and stone grit	6	+	–	+	–	23	23	23
5	12b	plant	9	+	–	–	+	24	33	28
6	13a	plant	9	+	–	–	+	20	18	19
7	13f	plant, grog and stone grit	11	+	–	–	+	21	25	23
8	14d	plant	8	–	+	–	+	27	30	29
9	14f	plant and stone grit	12	–	–	–	+	23	21	22
10	15b	plant	9	–	?	–	–	20	22	21
11	15c	plant and stone grit	12	–	?	–	–	19	24	22
13	16a	plant	7	–	–	–	+	37	38	38
14	17b	plant and stone grit	9	–	–	–	–	23	26	25
15	17f	plant and stone grit	10	–	–	–	–	20	20	20
17	20c	plant and stone grit	10	–	–	–	+	33	34	34
19	20m	plant, grog and stone grit	10	?	?	?	+	unknown	15	15
20	–	plant and stone grit	12	?	?	?	–	unknown	36	36
22	–	plant	12	?	?	?	–	unknown	25	25
23	–	plant	12	+	–	–	?	22	unknown	22
24	–	plant and stone grit	12	–	+	–	–	26	32	29
26	–	plant and stone grit	6	–	–	–	–	30	unknown	30
28	–	plant	11	?	?	?	+	unknown	24	24
29	–	plant	10	?	?	?	–	unknown	36	36
31	–	plant	16	?	?	?	–	unknown	30	30
32	–	plant	9	?	?	?	–	unknown	26	26

Tab. 2 Characteristics of the selected pots of Swifterbant S3.

Results

16 residues (64 %) provided information about their plant and non-plant food components. The remaining residues revealed rather featureless matrices, and, as such, provided no information about the original vessel contents. The results of the SEM analyses are presented as scanning electron micrographs (**figs 4-8**) and summarised in **table 3**.

The residues which revealed information about plant food cooked in the ceramic vessels can be divided into three main groups, generally representing cereal (group A with two subgroups A1 and A2) or non-cereal foods (groups B and C).

– Group A: Residues with epidermal fragments of emmer (*Triticum dicoccum*) chaff, suggesting food prepared including emmer grain

– – Subgroup A1: Residues with epidermal fragments of emmer chaff, without other plant or non-plant food components

Small to tiny fragments of chaff epidermis from emmer (*Triticum dicoccum*) were observed in seven residues (pots 3, 5, 7, 9, 14, 19 and 26). The epidermal remains were often embedded in thick layers of loose and coarse to moderately solid and fused residue matrices. The degree of preservation of the epidermis cell pattern varied from well-preserved (**fig. 4**) to rather deteriorated as a result of the process of food preparation and cooking. It is assumed that the epidermal remains derive from fine emmer chaff. Emmer is a »glume wheat« which, when threshed, breaks up into individual spikelets with the grain still tightly en-

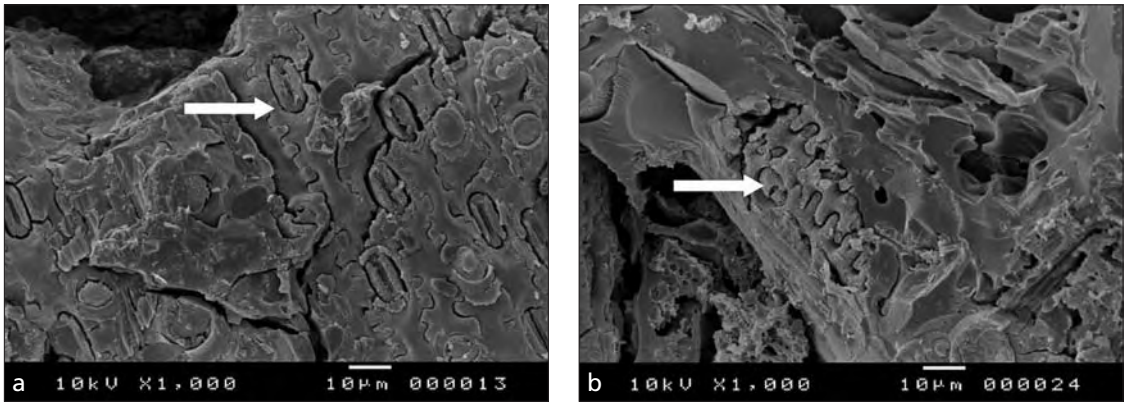

Fig. 4 SEM micrographs of two organic residues of pots 3 and 7 with epidermal remains of emmer chaff (*Triticum dicoccum*), suggesting food that comprised emmer grain. The silicified cell walls of epidermal long-cells with stomata, indicated by an arrow (**a**) and silicified epidermal long-cells, indicated by an arrow (**b**) are embedded in residue matrices. – (Photos L. Kubiak-Martens).

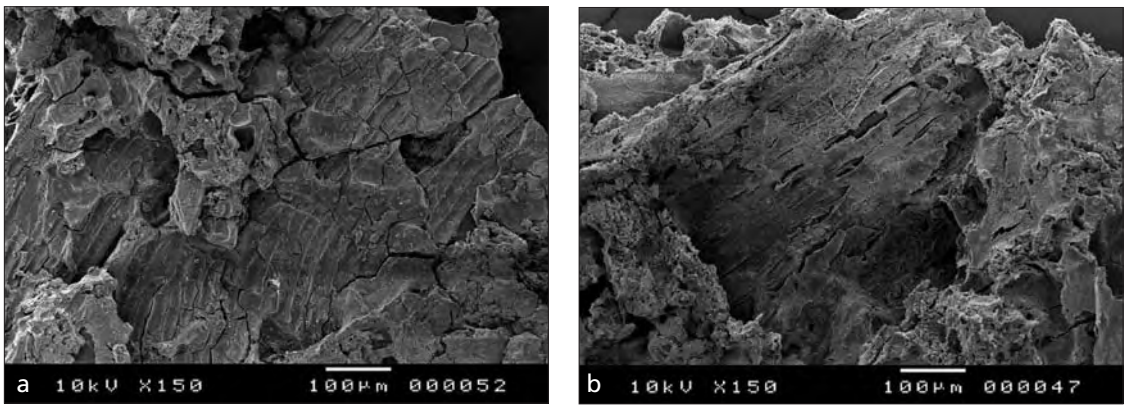

Fig. 5 SEM micrographs of two organic residues with fragment of fish scale embedded in the residue matrix of pot 15 (**a**) and possible bone remains embedded in the residue matrix of pot 11 (**b**). – (Photos L. Kubiak-Martens).

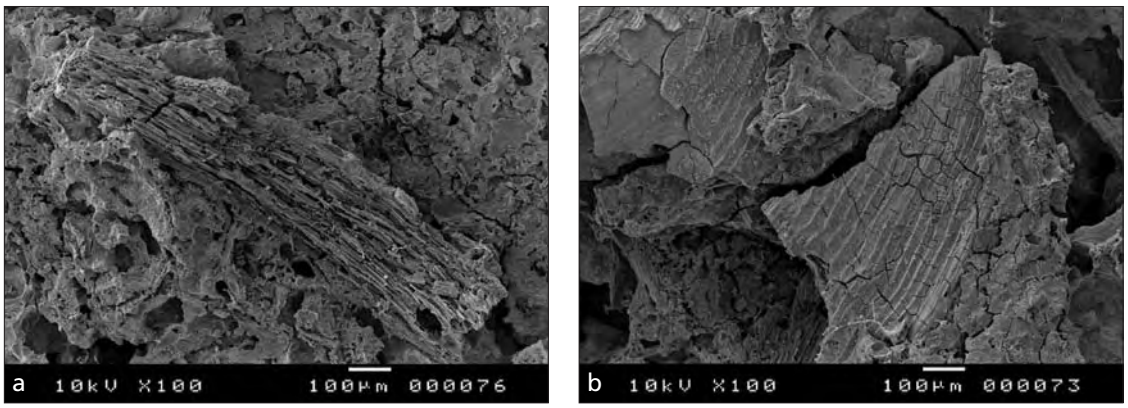

Fig. 6 SEM micrographs of an organic residue with remains of succulent stem tissue (**a**) and fragmented fish scale (**b**) embedded in the residue matrix of pot 23. – (Photos L. Kubiak-Martens).

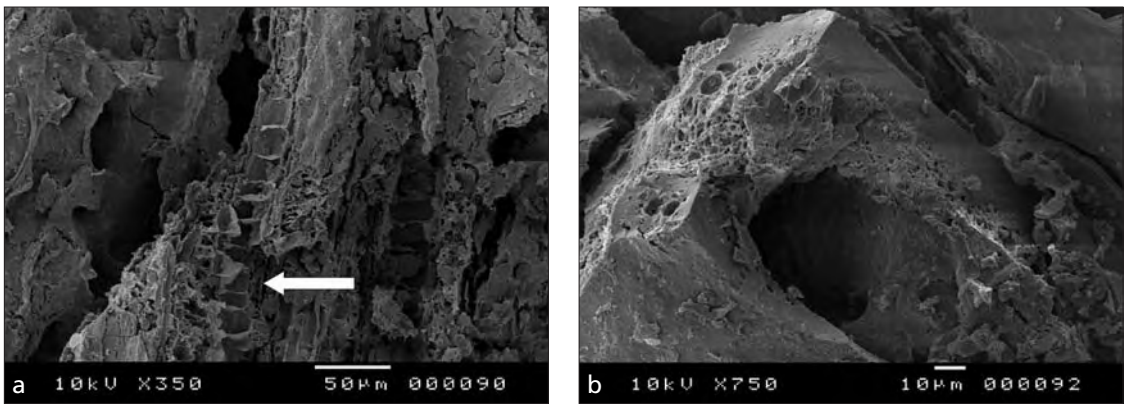

Fig. 7 SEM micrographs of an organic residue with remains of leaf tissue (**a**) and fragment of bone (**b**) embedded in the residue matrix of pot 24. The arrow indicates the row of parenchyma cells. – (Photos L. Kubiak-Martens).

closed by the surrounding chaff (glumes). It requires a further »dehusking« process to release the grain from the glumes. This succeeding stage of processing often includes the parching and pounding of the spikelets (Hillman 1984; van der Veen / Jones 2007). It is not surprising that even in what was considered »cleaned« emmer grain, some fine chaff remains might have survived both grain dehusking and subsequent cooking. The presence of emmer chaff in the organic residues studied here suggests that these remains originate from a food that was at least partly prepared from emmer grain.

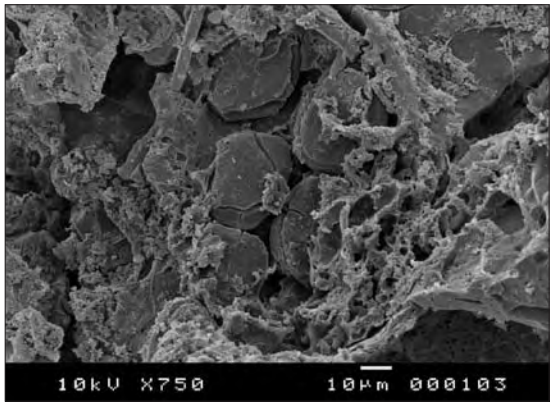

Fig. 8 SEM micrograph of an organic residue with starch granules c. 30 µm in diameter, embedded in the residue matrix of pot 28. – (Photo L. Kubiak-Martens).

– – Subgroup A2: Residues with epidermal fragments of emmer chaff with the additional presence of non-plant components

Three organic residues contain in addition to emmer chaff epidermis, remains of fish scales (pot 15; **fig. 5**) or possibly indeterminable animal bone remains (pots 11 and 20) embedded in residue matrices. The SEM images show a clear pattern of multiple bars outlining the texture of individual scale fragments. An identification of the fish species cooked in pot 15 is not possible, because the morphology of a complete scale is required for identification.

– Group B: Residues with stem and leaf tissues but without cereals, suggesting the cooking of green vegetables

The stem and/or leaf tissues were revealed in four residues on pots 17, 23-24 and 31. With the exception of the residue on pot 31, where no other plant or non-plant food component was noted, stem or leaf tissues were found together with fish scales (pots 17 and 23) or (possibly) indeterminable animal bone remains (pot 24). Three residues of this group (pots 17, 23 and 31) revealed the presence of stem tissues embedded in residue matrices. The amount of parenchymatous tissue observed in the stem fragments suggests that these derived from fleshy herbaceous stems or shoots of dicotyledon plant(s) (see **fig. 6**).

The SEM image of the residue on pot 24 (**fig. 7**) shows a group of thin-walled parenchyma cells, arranged in a row. This SEM image reveals a cross-section of a dicotyledon leaf mesophyll with either palisade parenchyma or spongy parenchyma cells (cf. Fahn 1990).

– Group C: Residue with starch granules, suggesting parenchymatous starchy food (possibly »root food«)

A recent study of starch microstructures in experimental and archaeological charred plant food remains demonstrated that, under sufficiently low charring temperatures of 220 °C and limited moisture content the starch structure may survive the process of food preparation and charring (cf. Valamoti et al. 2008). It appears that the organic residue on pot 28 revealed the presence of starch granules embedded in residue matrix. The group of elliptic starch granules, ranging from 30 to 35 µm with some signs of distorted edges, as result of food processing and/or cooking, is illustrated in **figure 8**. It is not possible to identify the plant species from which the starch was obtained. The concentration of starch granules and their relatively large size suggest that remains observed in this residue may originate from the underground storage organ of a plant.

Discussion of botanical results

Plant and non-plant elements were identified in 64 % of the ceramic vessels studied. What is perhaps the most distinctive feature of the Swifterbant S3 assemblage is the clear division of residues into those revealing an emmer grain component and those with no emmer.

pot	SEM	crust	SEM results	botany interpretation	SEM group
1	9.1		xylem tissue??	none	–
2	12		none defined	none	–
3	13-16	loose/porous	emmer chaff epidermis	emmer grain food	A1
4	17		none defined	none	–
5	18-21	loose/porous, thick crust	emmer chaff epidermis	emmer grain food	A1
6	22, 23		deteriorated plant tissue	none	–
7	24-27	thick crust, shiny	emmer chaff epidermis	emmer grain food	A1
8	40-42		deteriorated plant tissue	none	–
9	43	thick crust	deteriorated emmer chaff epidermis	emmer grain food	A1
10	45		none defined	none	–
11	47, 48	very solid	deteriorated emmer chaff epidermis; possibly bone fragment	emmer grain food, possibly with addition of none-plant component	A2
13	50		none defined	none	–
14	58	thick crust, loose/porous	deteriorated emmer chaff epidermis	emmer grain food	A1
15	51-57	course crust	deteriorated emmer chaff fish scale epidermis;	emmer grain food with fish	A2
17	65-68	fine	deteriorated plant tissue (possibly stem), fish scale	green vegetables with fish	B
19	70, 71	fine crust, thin layer, solid	deteriorated emmer chaff epidermis	emmer grain food	A1
20	80-84	thick, loose crust	deteriorated emmer chaff epidermis; bone fragment	emmer grain food with none-plant component	A2
22			not shown	none	–
23	72-79	thick, rather solid	stem tissue; fish scale	green vegetables with fish	B
24	90-95	rather solid, thick	stem tissue; possibly bone	green vegetables, possibly with none-plant component	B
26	99-101	fine layer, loose/not solid	deteriorated emmer chaff epidermis	emmer grain food	A1
28	103, 104	loose, fine layer	possibly starch grains	possibly root or other parenchymatous food	C
29			not shown	none	–
31	106, 107	thick to thin, shiny, some loose	stem tissue	green vegetables	B
32			not shown	none	–

Tab. 3 Results of SEM analysis.

The presence of fine epidermal remains of emmer chaff in many residues was demonstrated in SEM group A. This suggests that preparing emmer grain was a common cooking practice at the Swifterbant settlement. Even though not identified in the studied residues, barley may have also been used in cooking those cereal meals. Barley – which is a free-threshing cereal – would enter the cooking pots as truly clean grain and as such would be difficult to trace botanically in food residues.

Some residues from SEM group A revealed a well-fused, somewhat glassy microstructure of their matrices (**fig. 4**), suggesting that cereal grain was cooked in liquid/increased moisture content (cf. Valamoti et al. 2008). As no outlines of individual grains were preserved, it is difficult to specify whether the whole grain was used, or if the cereal grain was ground or pounded prior to cooking. What appears clear is that cereal grain was cooked as a porridge-like food. The excavation of S3 yielded 37 querns of which five were

studied for the presence of phytolites. This analysis indicated that grasses were pounded, but it remained uncertain whether it concerned cereals (Devriendt 2013).
Cereals were also cooked together with fish and possibly with meat (SEM subgroup A2). The presence of fish scales in residues is of particular interest to us because it offers the first direct evidence of fish cooking in the Swifterbant culture. In at least three pots multiple fish scales were detected. The most likely explanation of their presence is the cooking of fish in the pot. Even though it was considered as »clean« and ready for cooking, the fish most certainly had a few remaining scales attached to its skin. In Swifterbant, fish was cooked with cereals (as indicated for pot 15) or with the addition of green vegetables (pots 17 and 23). As suggested by archaeozoological remains, fish was an important dietary element at Swifterbant (13 fish species were identified at S3 site; Zeiler 1997). Until now, however, no direct evidence existed for the methods that were used in preparing fish. Indirect evidence derives from the fact that radiocarbon dates made on food residues encrusted on Swifterbant pottery are all influenced by a reservoir effect, presumably due to cooking fish (Raemaekers 2005; Fisher / Heinemeier 2003).
Clear indication of the presence of stem and leaf tissues of herbaceous plants was found in SEM group B. This suggests that various stems/shoots and leaves were used at Swifterbant as green vegetables, cooked together with other foods rather than being themselves the main component. Because the plant foods available to people living in Swifterbant are known from earlier archaeobotanical studies (van Zeist / Palfenier-Vegter 1984), suggestions can be made as to which plants were used as green vegetables. There are a number of species in the Swifterbant seed assemblage that are good examples of plants with edible fleshy or succulent stems, leaves and/or shoots. This group includes glasswort (*Salicornia europaea*), sea aster (*Aster tripolium*), various orache species (*Atriplex* spp.), fat-hen (*Chenopodium album*), sharp dock (*Rumex conglomeratus*), stinging nettle (*Urtica dioica*), greater burdock (*Arctium lappa*) and chickweed (*Stellaria media*). All these plants may have been used as green vegetables. They were most certainly added to other foods such as fish and meat, rather than being themselves the main food component. Some may have been eaten raw; others, such as the greens of fat-hen, would have simply tasted better when cooked (Mears / Hillman 2007). Most of these plants, however, are available in a palatable and digestible form only in their young stages. The young succulent green stems of glasswort and the leaves of sea aster may have been collected at some distance from the site. Young plants of greater burdock, fat-hen, stinging nettle and chickweed would have been available for gathering close to or even on the Swifterbant settlements. Green vegetables can be expected to have a high moisture content, vitamins (vitamin C and folic acid) and minerals (such as iron, calcium and magnesium). Some greens, for example the leaves of stinging nettle, also contain a considerable amount of protein in addition to vitamin C, fat and minerals (Kuhnlein / Turner 1991; Mears / Hillman 2007).

CHEMICAL RESIDUE ANALYSIS

Methods: direct temperature-resolved mass spectrometry (DTMS)

Direct temperature-resolved mass spectrometry (DTMS) is a powerful tool in the chemical analysis of very small samples (50 µg) of complex solid organic materials. DTMS makes it possible to characterise the complete chemical composition of the material, including both volatile, extractable compounds and non-extractable solid compounds (Boon 1992). The chemical DTMS »fingerprint« gives information about a broad range of compounds such as lipids, waxes, terpenoids, polycyclic aromatic hydrocarbons (PAH's), oligosaccharides, small peptides and protein fragments, and a whole range of thermally stable more or less condensed, poly-

meric components (commonly called »charred«, or »carbonised«). Within archaeological research DTMS techniques and other comparable pyrolysis techniques have primarily been applied to study complex organic solids such as carbonised grains and pulses (Braadbaart et al. 2004a; Braadbaart et al. 2004b), pitches, tars and resinous materials (Regert / Rolando 2002; Regert et al. 2003; Colombini / Modugno / Ribechini 2005; van Gijn / Boon 2006; Ribechini et al. 2011), and food and non-food coatings on ceramics (Oudemans / Boon 1991; Oudemans / Boon 1996; Colombini et al. 2005; Oudemans / Eijkel / Boon 2007).

The DTMS technique basically employs the mass spectrometer to monitor the organic compounds released from a solid sample as the temperature is increased. Due to the controlled circumstances in the DTMS instrument (absence of oxygen and controlled temperature increase), the fragments that are released are formed in a predictable way. Each fragment (or group of fragments) visible in a mass spectrum is indicative of specific original material. When such »biomarkers« are detected they can be used to identify the original material (Boon 1992).

The mass spectrometer used was a JEOL JMS SX/SX 102A (four sectors) tandem mass spectrometer. The following mass spectrometer conditions were applied: 16 eV electron ionisation voltage, 8 kV acceleration voltage, a scanning range of mass m/z 20-1000, and a scanning speed of 1 scan per second. Data were collected with the use of a JEOL MS-MP9021D/UPD data system and an appropriate software. Prior to DTMS analysis a small amount of sample (50 µg) is pulverised and homogenised in a small glass mortar and pestle after additional of 10-50 µl of ethanol. A small amount (2-5 µl) of the sample suspension is applied to the filament of the mass spectrometer, dried (in vacuum) and subsequently analysed.

Results

The results of the DTMS analyses are a series of mass spectra. Since specific masses (or groups of masses) indicate the presence of specific compounds in archaeological residues (Oudemans / Eijkel / Boon 2007) the compound classes could be scored per sample and are summarised in the **annex**. A total of 25 residues were studied, of which 17 residues (68 %) render useful information about the original vessel content. The other eight residues contained insufficient organic material (nos 1, 15, 23 and 26); were contaminated (nos 3, 13 and 19) or comprised primarily poly-aromatic compounds indicative of soot (no. 7).

The 17 residues that contained enough organic material to (partially) identify the original vessel content could be divided into two main groups: group A includes 15 residues that contain mixtures of proteins, polysaccharides and lipids; while group B includes three residues that comprise mixtures of proteins and lipids only. Group A could be divided into three subgroups.

– Group A: Residues with a more or less carbonised mixture of proteins, polysaccharides and lipids.

– – Subgroup A1: These residues have undergone a limited amount of heating and contain a well-preserved lipid profile, including unsaturated fatty acids, some intact acyl-lipids and sterols indicating both animal and plant origins (pots 4-5, 9-10, 20, 24 and 31-32). In one residue indications for beeswax are present (pot 5).

– – Subgroup A2: Residues with medium to severely charred protein and polysaccharide, mixed with a small amount of degraded fat (pots 6, 8, 11 and 28). One vessel may also belong to this group, but contains additional a small amount of resin (possibly originating from [modern] roots material) (pot 17).

– – Subgroup A3: Residues with a relatively high degree of carbonisation. These residues contain only lipids of a highly degraded nature such as unsaturated free fatty acids. The sterols no longer give a clear indication of an animal or plant origin (pot 14).

– Group B: Residues with medium to severely heated proteins, mixed with a small amount of degraded fat (pots 2, 22 and 29). No indications for polysaccharides are present.

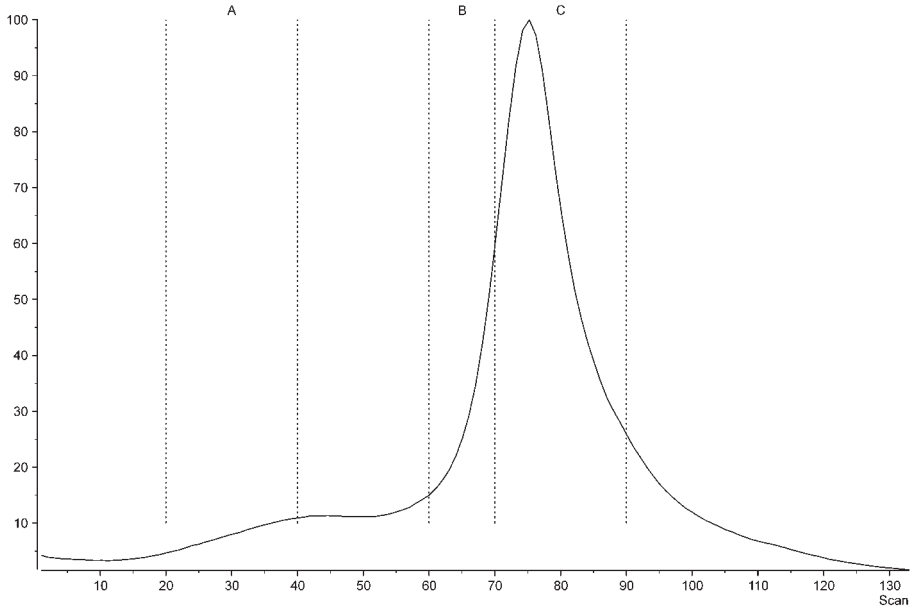

Fig. 9 Total ion current (TIC) of the residue on pot 10 showing desorption phase A (scan 20-40), early pyrolysis phase B (scan 60-70) and later pyrolysis phase C (scan 70-90). – (Diagram E. Bolhuis; data T. F. M. Oudemans).

One residue of subgroup A1 is discussed in detail below, to give an impression of the various indicative masses present in a DTMS spectrum. The results are represented in the DTMS total ion current (TIC) (**fig. 9**) and various mass spectra (**figs 10-12**). The height of the TIC signal and the form of the peak indicate that the residue contains a large amount of organic material of a homogeneous nature with a low degree of condensation (due to limited thermal degradation). In desorption phase A (scan 20-40) volatile compounds such as lipids are visible. The pyrolysis phase is divided in an early pyrolysis phase B (scan 60-70) and a later pyrolysis phase C (scan 70-90) and depicts the larger non-volatile compounds such as proteins and polysaccharides.

The mass spectrum of desorption area A (scan 20-40; **fig. 10**) shows a relatively well-preserved lipid profile. Lipids are clearly present as (saturated and unsaturated) free fatty acids as well as intact diacylglycerols (DG with 26-34 carbon atoms are visible). Clear markers for the presence of cholesterol (*m/z* 368 and 386) indicate an animal origin. Further analysis of the acyl-lipids shows that the animal component originates from meat fat, rather than from milk fat (short carbon chains typical of milk fats are absent). The presence of markers for plant sterols such as campesterol (*m/z* 382 and 400) in combination with the presence of unsaturated free fatty acid C18:1 in relatively high amounts suggest the additional presence of a plant oil origin. The mass spectra (**figs 11-12**) for early pyrolysis phase B (scan 60-70) and later pyrolysis phase C (scan 70-90) are very similar, only varying in the relative intensity of masses. Both mass spectra show a mixture of markers for heated polysaccharides and proteins. In summary, residue no. 10 reveals a medium charred mixture of polysaccharides, proteins and lipids with a relatively well-preserved lipid profile. The lipids suggest a mixed origin of animal meat fat and plant oils.

Discussion of DTMS results

The chemical preservation of the organic residues on ceramics from S3 is relatively good, in 68 % of the residues, indicators could be detected that gave useful information about the original vessel content. The three most common groups of chemical compounds occurring in food (proteins; carbohydrates or polysaccharides in the form of sugars and starches; and lipids in the form of fats and oils), also occur in these residues studied.

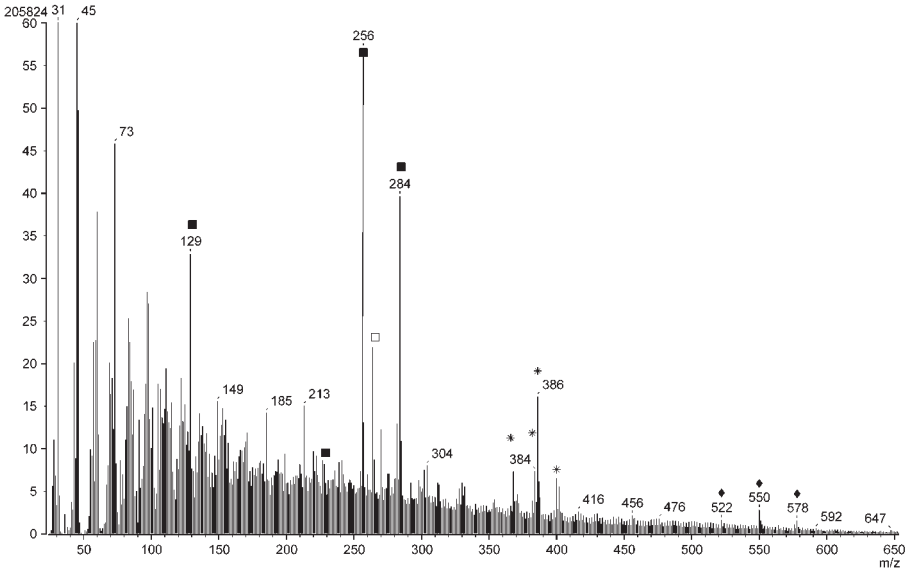

Fig. 10 The mass spectrum of desorption phase A (scan 20-40) of the residue on pot 10 is characterised by a well-preserved lipid profile including fatty acids (■ saturated; □ unsaturated) and intact acyllipids (◆). Markers for sterols (✳) indicate both animal and plant origin. – (Diagram E. Bolhuis; data T. F. M. Oudemans).

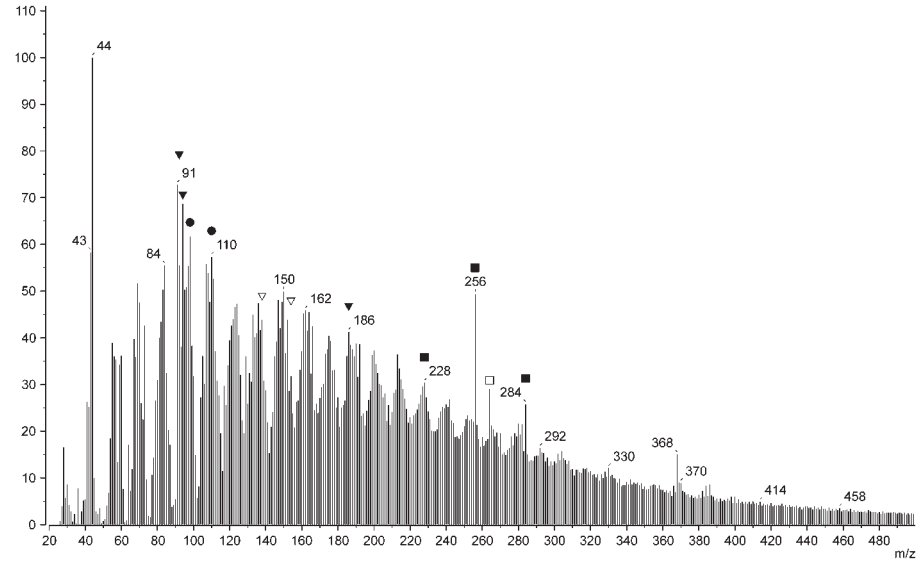

Fig. 11 The mass spectrum of early pyrolysis phase B (scan 60-70) of the residue on pot 10 is characterised by indicators for charred polysaccharides (●), fatty acids (■ saturated; □ unsaturated), markers for intact peptides and proteins (▽) and charred protein markers (▼). – (Diagram E. Bolhuis; data T. F. M. Oudemans).

It is significant to notice that all 17 residues contain protein remains, which shows that the Swifterbant people always included some kind of proteinaceous material in their cooking. Proteins in human foods most commonly originate from animals, fish, birds or shellfish (for instance in the form of meat, skin, blood, milk, eggs, or cartilage). However, proteins also occur in much lower concentrations in certain edible plant materials (i. e. in pulses, beans, and seeds and in some roots or sprouts). The chemical characteristics of heated or charred proteins render extremely complex DTMS spectra that often cannot be traced back to a specific original material (Braadbaart et al. 2004b; Oudemans / Eijkel / Boon 2007). In our analysis, it was possible to determine the presence of proteins but not to determine an animal or plant origin.

Lipids (oils and fats) are usually relatively well preserved in archaeological residues. The best preservation of indicative lipids occurs in soils containing little oxygen (Evershed 2008). In general it can be said that most lipid profiles in archaeological residues originate from so-called hard fats from the meat of large land mammals (cattle, pigs, sheep, deer, wild boar etc.). These fats are most easily preserved. Sometimes short chain fatty acids occur in lipid profiles indicating that milk fats of goats or sheep are present (Oudemans /

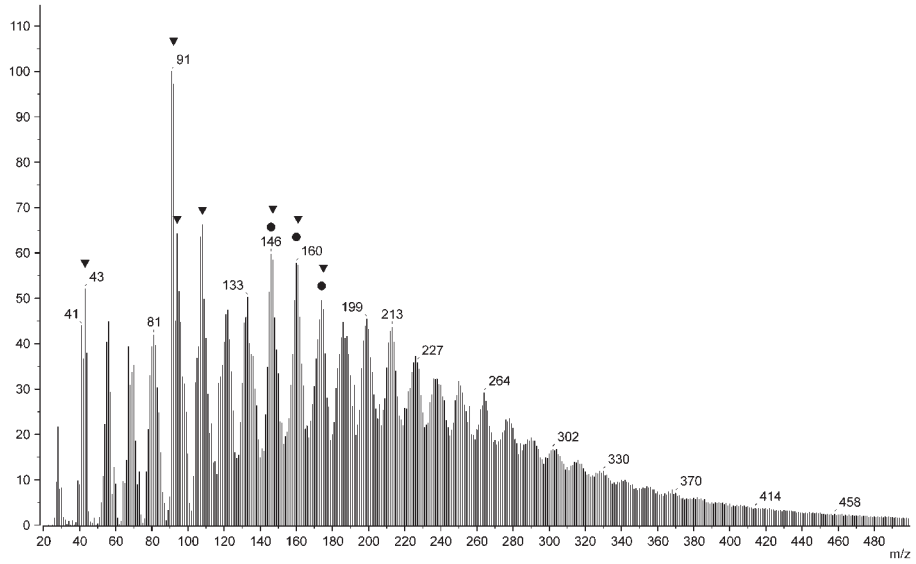

Fig. 12 The mass spectrum of late pyrolysis phase C (scan 70-90) of the residue on pot 10 is characterised by indicators for charred polysaccharides (●), and charred protein markers (▼). – (Diagram E. Bolhuis; data T. F. M. Oudemans).

Boon 2007). In some cases, lipid profiles contain a lot of unsaturated fatty acids, which can suggest the presence of a plant oil or fat. Fish oils and fats of marine mammals also contain significant amounts of unsaturated or polyunsaturated fatty acids (Regert 2011). However, the degradation of unsaturated lipids through heating or oxidation causes these compounds to easily lose their specific characteristics. It is therefore often difficult to identify fish fat, plant oils or marine mammal fats in archaeological residues. The residues from S3 contain lipids, but their overall preservation is not exceptional. Only a few of them have a lipid profile including unsaturated fatty acids or large amounts of intact acyl-lipids. In the residues of S3 there are indications of meat fat and plant oil (such as in no. 10) but no indications are found for the presence of milk fats.

Animal and plant sterols (and their degradation products) can give useful additional information about the origin of residues. Cholesterol (sometimes in combination with its oxidation products) is an indicator for an animal origin (including birds and fish). Phytosterols such as brassicasterol, campersterol, sitosterol, stigmasterol and their dehydrogenation products suggest lipids originating from a plant source. Sterols are relatively well preserved in the residues from S3. Many residues contain both cholesterol and indicators for phytosterols suggesting that the lipids have a mixed animal and plant origin. Some residues show only cholesterol markers.

Intact polysaccharides, or longer chain carbohydrates (such as present in sugars and starches), have relatively little chance to survive in heated or charred archaeological residues. Not only because they are relatively water-soluble, but also because they are very sensitive to heating. At temperatures above 220 °C carbohydrates tend to lose their specific characteristics and at temperatures above 300 °C it is virtually impossible to determine a carbohydrate component. If temperatures remain under 300 °C charred polysaccharides can still be identified. Carbohydrates (both sugars and starches) originate from plant materials. And although prehistoric diets may have contained some pure sugars (in the form of honey, fruits, some roots and berries), most carbohydrates were consumed in the form of starches. Starches are produced by plants to preserve energy for later use and are stored in roots and bulbs, and in seeds, beans, fruits and cereals. Many residues from S3 show the presence of more or less charred polysaccharides (all residues from DTMS group A) indicating the presence of a significant amount of starch in the original vessel content, in combination with a limited thermal degradation (although residues from subgroups A2 and A3 are more thermally degraded then those from A1). It is meaningful to notice that the residues from DTMS group B do not contain any such compounds indicating the absence of starches from the original vessel content.

pot	temper	wall thickness (mm)	decoration	generalised diameter (cm)	SEM group	DTMS group	functional group
1	plant	7	+	12	–	–	
2	plant	7	+	12	–	B	1
3	plant and stone grit	7	+	25	A1	–	2
4	plant and stone grit	6	+	23	–	A1	2?
5	plant	9	+	28	A1	A1	
6	plant	9	+	19	–	A2	
7	plant, grog and stone grit	11	+	23	A1	–	2
8	plant	8	+	29	–	A2	
9	plant and stone grit	12	+	22	A1	A1	2
10	plant	9	?	21	–	A1	
11	plant and stone grit	12	?	22	A2	A2	2
13	plant	7	+	38	–	–	
14	plant and stone grit	9	–	25	A1	A3	2
15	plant and stone grit	10	–	20	A2	–	2
17	plant and stone grit	10	+	34	B	A2 + resin	
19	plant, grog and stone grit	10	+	15	A1	–	2
20	plant and stone grit	12	?	36	A2	A1	2
22	plant	12	?	25	–	B	1
23	plant	12	+	22	B	–	1
24	plant and stone grit	12	+	29	B	A1	
26	plant and stone grit	6	–	30	A1	–	2
28	plant	11	+	24	C	A2	1
29	plant	10	?	36	–	B	1
31	plant	16	?	30	B	A1	1
32	plant	9	?	26	–	A1	

Tab. 4 Combination of temper, SEM and DTMS results and functional groups.

GENERAL DISCUSSION AND CONCLUSIONS

In the combined botanical and chemical analysis 18 residues rendered enough information to be given a final functional classification. Seven residues remained undetermined due to the fact that the absence of an outcome in the SEM or DTMS analysis made it impossible to determine a specific residue category. Two large functional groups could be distinguished (tab. 4).

Group 1 consists of six residues that contain no indications for the presence of emmer. The residues contain botanical remains but lack emmer (SEM group B or C) or show no botanical evidence at all and lack polysaccharides in the chemical analysis (DTMS group B). Group 1 represents six pots used for non-emmer meals. The pots are tempered with plant material only (nos 2, 22-23, 28-29 and 31).

Group 2 is consisting of nine residues that contain emmer remains (SEM group A) and mostly show chemical markers for polysaccharides (DTMS group A). Group 2 represents nine pots used for meals including emmer. The pots are tempered with plant and stone grit and sometimes grog (nos 3, 7, 9, 11, 14-15, 19-20 and 26).

These two groups represent 15 of the 18 pots that could be given a final functional classification combining ceramic temper, SEM and DTMS characteristics (83 %), leaving only two small subgroups outside the dichotomy (fig. 13).

Group 1

Group 1 pots are used to cook meals without emmer. Both botanical and chemical evidence suggest the pots in group 1 were primarily used to cook protein-rich stew-like meals containing fish or meat, sometimes in combination with green vegetables or starch-rich plant parts such as roots, bulbs, seeds, beans or fruit. Such combinations seem completely in Mesolithic style. Not all pots revealed SEM results. The pots in this group (nos 23, 28 and 31) that did contain SEM evidence, showed remains of green vegetables (pot 31), accompanied by fish scales (pot 23) and starch-rich plants – possibly »root food« (pot 28). The absence of emmer is significant because small fragments of emmer chaff epidermis are usually the best-preserved plant remains observed in organic residues (Kubiak-Martens 2008; Oudemans / Kubiak-Martens 2012). So it would be very unlikely that emmer was cooked in a pot and no traces were found during SEM examination.

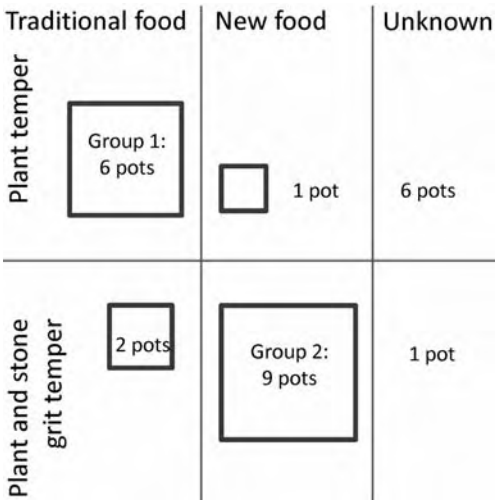

Fig. 13 Correlation between temper and the function of pots. The surface of the squares is related to the number of pots in the two functional groups and the two subgroups outside the proposed dichotomy. – (Illustration D. C. M. Raemaekers).

The chemical analysis showed strong evidence of almost purely proteinaceous materials with some lipids in three of the pots (nos 2, 22 and 29) and two remaining pots (nos 28 and 31) containing clear indications for a mixture of proteins, carbohydrates and lipids. The carbohydrates in these residues must have originated from a source other than emmer. At S3, oak acorns are a potential source of carbohydrates. Acorns are considered an important starchy food in pre-agrarian and early agrarian North-West Europe (Jørgensen 1977; Mason 1995; Kubiak-Martens 1999). Their nutritional content can be compared with that of cereals, being largely a source of starch with a small amount of protein and fat (Kuhnlein / Turner 1991). Residues encrusted on Early Neolithic (Funnel Beaker) vessels from the site of Neustadt-LA 156 (Kr. Ostholstein) were proposed to have originated from cooking acorns (Saul et al. 2012). As for pots from group 1, cooking roots or other underground storage organs may also be considered as a source of starchy food. In one of the residues (pot 28), the presence of starch grains embedded in (what appears to be remnants of) parenchymatous tissue suggests that root or other parenchymatous underground storage organs were cooked in the vessel.

Although proteins in prehistoric foods often originate from animal sources (including birds, fish or mammals), a number of plant species present in Swifterbant S3 plant macro-remains assemblage, could be the source of plant protein for residues of group 1 (pot 31). At Swifterbant, large amounts of waterlily (*Nymphaea alba*) seeds were found (van Zeist / Palfenier-Vegter 1984), suggesting that they might have been collected for food. The seeds of various waterlilies (*Nymphaea* spp. and *Nuphar* spp.) are rich in starch and protein, and there is strong evidence from the Late Mesolithic Ertebølle site of Halsskov (Reg. Sjælland/DK) and from the Late Mesolithic Hoge Vaart (prov. Flevoland/NL) of waterlily seeds being used as food (Kubiak-Martens 2002; Brinkkemper et al. 1999, respectively). The Swifterbant S3 examples could certainly include seeds of various members of chenopod (or goosefoot) family. The overwhelmed presence of seeds from orache group (*Atriplex patula/prostrata*) and fat-hen (*Chenopodium album*) in the macro-remains assemblage suggests that both might have served as a source of protein-rich food at S3 site. The potential use of fat-hen seeds (which are particularly rich in protein, carbohydrates and contain some fat) as food has been often emphasised in the archaeobotanical literature (e. g. Moore / Hillman / Legge 2000). At Swifterbant, the seeds might have been ground into the mush and consequently be responsible for the proteinaceous part

of the residues in some pots from group 1 (pot 31). The chenopods might have also been added to cereals as the protein-rich plant component is also detected in residues with emmer grain in group 2 vessels.
Most residues from group 1 contain little or no lipids (pots 2, 18, 22 and 29); some contain a distinctive amount of lipids in addition to proteins and polysaccharides (pots 28 and 31). Most residues on group 1 show only indications for animal lipids (including mammals, fish or fowl) confirming our earlier model of a Mesolithic stew. One exception (pot 31) seems to contain lipids from a plant origin as well. The Swifterbant S3 archaeobotanical record presented us with at least one species – hazelnut (*Corylus avellana*) – which might have contributed to the local diet as a source of plant oil.

Group 2

Group 2 pots are used for cooking cereal-based porridge occasionally cooked together with fish and/or animal meat. The residues are defined by the presence of emmer remains and (in many cases) the additional presence of carbohydrates in the chemical analysis. Plant remains other than emmer have not been found. However, both SEM results and DTMS results suggest the presence of more than just cereals. SEM results indicate the presence of bone material (pots 11, 14 and 20). In pot 14 it is clear that it concerns fish. DTMS results are in agreement with these findings and showed that half the pots in this group (nos 4, 9, 11, 14 and 20), contain lots of proteins and sometimes lipids that are (at least partially) of animal origin. The indications sometimes point in the direction of an exclusive animal material (pots 11 and 14) or a combined plant and animal material (pots 4, 9 and 20).
Both emmer and naked barley were used at S3. This is known from earlier archaeobotanical studies (van Zeist / Palfenier-Vegter 1984). Even though not identified in SEM analysed residues, naked barley may have also been used in cooking these cereal meals. In contrast to emmer, barley is a free-threshing cereal. As a result, there is only a very limited chance that the (grinded) grains would enter the cooking pots along with its chaff. Consequently barley, once cooked as »clean-grain« would be difficult to trace botanically in food residues. Whether emmer and barley were cooked together remains difficult to answer. There are some indications that emmer and barley were not cooked together. Two Neolithic sites in the Netherlands (Schipluiden [prov. Zuid-Holland] and Zeewijk [prov. Noord-Holland]), with remains of both emmer and barley, showed charred lumps of porrage-like food made exclusively of emmer, suggesting that emmer was cooked seperately (Kubiak-Martens 2006). It is therefore possible that barley may be missing from S3 pots in group 2, because those cereals were never cooked together. However, this does not explain how barley was cooked, in general.

CONCLUSIONS

It can be concluded that ceramics from the site of Swifterbant S3 can be divided into two subgroups each with a specific use. This is intriguing while at superficial glance (fig. 2) the two subgroups are not easily distinct in form or size. However, the fact that the correlations in sherd characteristics are similar at different sites (S2, S3 and S4), suggests that the potters deliberately produced and reproduced two function vessel groups and that the two function groups are a shared cultural characteristic.
Looking at the results from a chronological perspective, a somewhat surprising conclusion must be drawn. Early Swifterbant ceramics found at Hoge Vaart (Haanen / Hogestijn 2001), Polderweg (prov. Zuid-Holland/NL; Raemaekers 2001a) and De Bruin (prov. Zuid-Holland/NL; Raemaekers 2001b) cannot be divided in two subgroups on the basis of their ceramic characteristics. These ceramics are mostly thick-walled pots tempered with stone grit and only sporadically decorated; they clearly resemble the group 2 pots. As Early

Swifterbant concerns the final phase of the Mesolithic in our area (Brinkkemper et al. 1999), it must be assumed that the meals in these pots did not include emmer or any other cereals. In other words, with the introduction of cereals in the cooking process, the traditional meals were transferred to a new type of pottery (group 1), while the *nouvelle cuisine* ended up in the traditional pots (group 2).

This case study is a strong clue that the introduction of cereals in the diet of the Swifterbant people was an innovation embedded in meaningful action. As such, it is an important clue that this step in the process of Neolithisation was perceived as significant. While this may seem self-evident, it is important not to consider this significance as a given but as the outcome of research. Similar studies on Early Neolithic ceramics across Europe, combining archaeology, SEM and DTMS, are much needed to appreciate mankind's constructions of a meaningful material world.

ANNEX

Results of the DTMS analysis. Absence and presence of various compound classes is scored. Compounds classes cored: carbondioxide (CO_2); saturated fatty acids (SFA); unsaturated fatty acids (UFA); intact acyl-lipids (AG); intact proteins and peptides (PP); charred proteins and amino acids (PC); intact polysaccharides (Ps); charred polysaccharides (PsC); sterols (St) of animal (A) or plant (P) orgin; and contamination by sulfur containing compounds (S). the absence or presence as well as the amount of compounds present in the DTMS spectra is indicated: – = absent; ± = traces are present; + = present in low amounts; ++ = present in higher amount; +++ = present in very high amount.

Pot 1: CO_2: +++; SFA: –; UFA: –; AG: –; PP: –; PC: +; Ps: ±; PsC: ±; St: –; S: +; DTMS results: Low organic content. Mostly calcium carbonate; DTMS group: –.

Pot 2: CO_2: ++; SFA: ±; UFA: –; AG: –; PP: +; PC: +++; Ps: –; PsC: ±; St: A/P; S: ++; DTMS results: A strong protein component and few lipids. Sterols indicate both animal and plant origin; DTMS group: B.

Pot 3: CO_2: +; SFA: –; UFA: –; AG: –; PP: –; PC: ±; Ps: ±; PsC: ±; St: –; S: +++; DTMS results: Contamination; DTMS group: –.

Pot 4: CO_2: –; SFA: +++; UFA: ++; AG: +; PP: ±; PC: ++; Ps: ±; PsC: +; St: A/P; S: +; DTMS results: Low to medium degree of thermal degradation (TD). High concentration of (partially unsaturated) lipids as well as proteins. A polysaccharide component is also present. Sterols indicate both animal and plant origin. Not enough intact acyl-lipids to identify the origin of the lipids in more detail; DTMS group: A1.

Pot 5: CO_2: +; SFA: ++; UFA: +; AG: +; PP: ±; PC: ++; Ps: ±; PsC: +; St: A/P; S: –; DTMS results: Medium to high degree of TD. High concentration of (partially unsaturated) lipids as well as proteins. A polysaccharide component is also present. Sterols indicate both animal and plant origin; DTMS group: A1.

Pot 6: CO_2: +; SFA: +; UFA: –; AG: ±; PP: ±; PC: ++; Ps: ±; PsC: +; St: A/P; S: ++; DTMS results: Medium degree of TD. Mixture of proteins and polysaccharides. Few lipids. Sterols indicate both animal and plant origin. Some contamination with sulphur; DTMS group: A2.

Pot 7: CO_2: +++; SFA: +; UFA: –; AG: –; PP: ±; PC: +; Ps: –; PsC: –; St: –; S: ++; DTMS results: Mostly calcium carbonate, mixed with poly-aromatic compounds and a very small amount of lipids and proteins; DTMS group: –.

Pot 8: CO_2: ++; SFA: +; UFA: ±; AG: ±; PP: +; PC: ++; Ps: ±; PsC: +; St: A/P; S: ++; DTMS results: Medium degree of TD. Mixture of proteins and polysaccharides. Few lipids. Sterols indicate both animal and plant origin. Some contamination with sulphur; DTMS group: A2.

Pot 9: CO_2: +; SFA: +++; UFA: +; AG: –; PP: +; PC: ++; Ps: ±; PsC: +; St: A/P?; S: –; DTMS results: Medium degree of TD. High concentration of lipids (partially unsaturated) and proteins. A polysaccharide component is also present. Sterols indicate mostly animal origin (possibly some plant). Not enough intact acyl-lipids to identify the origin of the lipids in more detail; DTMS group: A1.

Pot 10: CO_2: –; SFA: +++; UFA: +++; AG: +; PP: ++; PC: +++; Ps: ++; PsC: +; St: A/P; S: –; DTMS results: Lightly heated char with lots of well-preserved lipids (including unsaturated fatty acids), proteins and polysaccharides. Sterols indicate animal (meat fat) and plant origin; DTMS group: A1.

Pot 11: CO_2: +; SFA: +; UFA: –; AG: –; PP: +; PC: ++; Ps: ±; PsC: +; St: A?; S: ++; DTMS results: Low to medium degree of TD. Mixture of proteins and polysaccharides. Few lipids. Sterols indicate a possible animal origin. Some contamination with sulphur; DTMS group: A2.

Pot 13: CO_2: +; SFA: +; UFA: –; AG: –; PP: ±; PC: ++; Ps: –; PsC: ±; St: A/P; S: +++; DTMS results: Contamination; DTMS group: –.

Pot 14: CO_2: +++; SFA: ++; UFA: +; AG: –; PP: ±; PC: +; Ps: –; PsC: ±; St: A?; S: ±; DTMS results: Medium to high degree of TD. Mostly charred proteins (some polysaccharides). Few lipids. Sterols indicate probably animal origin; DTMS group: A3.

Pot 15: CO_2: +++; SFA: +; UFA: ±; AG: –; PP: ±; PC: +; Ps: –; PsC: ±; St: –; S: ++; DTMS results: Low organic content. Mostly calcium carbonate; DTMS group: –.

Pot 17: CO_2: +; SFA: +; UFA: –; AG: ±; PP: ++; PC: +++; Ps: –; PsC: +; St: A/P; S: ++; DTMS results: Low to medium degree of TD. Mixture of a lot of proteins and some polysaccharides. Medium

amount of lipids. Sterols indicate animal and plant origin. Some contamination with sulphur. A small amount of resin (possibly originating from [modern] root material); DTMS group: A2 + resin.

Pot 19: CO_2: –; SFA: –; UFA: –; AG: –; PP: ±; PC: +; Ps: ±; PsC: +; St: –; S: +++; DTMS results: Contamination; DTMS group: –.

Pot 20: CO_2: +; SFA: +; UFA: –; AG: +; PP: ±; PC: ++; Ps: +; PsC: +; St: A/P?; S: +; DTMS results: Low degree of carbonisation – strong protein component and medium amount of relatively well-preserved lipids (partially unsaturated). A polysaccharide component is also present. Sterols indicate mostly animal origin (possibly some plant). Very few intact acyl-lipids remain, not enough to identify origin of lipids in more detail; DTMS group: A1.

Pot 22: CO_2: +++; SFA: ±; UFA: –; AG: –; PP: ++; PC: +++; Ps: –; PsC: ±; St: A/P; S: +; DTMS results: Medium degree of TD. A strong protein component and few lipids. Sterols indicate both animal and plant origin; DTMS group: B.

Pot 23: CO_2: ++; SFA: –; UFA: –; AG: –; PP: +; PC: +; Ps: –; PsC: ±; St: –; S: ±; DTMS results: Low organic content. Mostly calcium carbonate; DTMS group: –.

Pot 24: CO_2: ++; SFA: ++; UFA: –; AG: +; PP: +; PC: +++; Ps: +; PsC: +; St: A/P; S: ±; DTMS results: Medium degree of TD. A strong protein component and medium amount of relatively well-preserved lipids (partially unsaturated). A polysaccharide component is also present. Sterols indicate both animal and plant origin. The lipid spectrum indicates a meat fat origin; DTMS group: A1.

Pot 26: CO_2: ++; SFA: +; UFA: –; AG: –; PP: ±; PC: ++; Ps: ±; PsC: ±; St: A?; S: +; DTMS results: Low organic content. Mostly calcium carbonate; DTMS group: –.

Pot 28: CO_2: +; SFA: ++; UFA: +; AG: ±; PP: ++; PC: +++; Ps: ±; PsC: +; St: A?; S: +; DTMS results: Medium to high degree of TD. Mixture of proteins and polysaccharides. Few lipids. Sterols indicate a possible animal origin; DTMS group: A2.

Pot 29: CO_2: +; SFA: +; UFA: ±; AG: –; PP: ++; PC: +++; Ps: ±; PsC: ±; St: A?; S: –; DTMS results: Very low organic contents – low degree of carbonisation – strong protein component and few lipids. Sterols indicate a possible animal origin; DTMS group: B.

Pot 31: CO_2: +; SFA: ++; UFA: +; AG: +; PP: +; PC: +++; Ps: ±; PsC: +; St: A/P; S: ±; DTMS results: Lightly carbonised char with a high concentration of well-preserved lipids (including unsaturated fatty acids), proteins and polysaccharides. Sterols indicate animal and plant origin. Animal lipids originating from animal meat; DTMS group: A1.

Pot 32: CO_2: +; SFA: ++; UFA: +; AG: +; PP: ++; PC: ++; Ps: +; PsC: +; St: A/P; S: ±; DTMS results: Low organic contents – lightly carbonised char with medium-preserved lipids (including unsaturated fatty acids), proteins and polysaccharides. Sterols indicate animal and plant origin. Animal lipids originating from animal meat; DTMS group: A1.

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Zusammenfassung / Abstract / Résumé

Neues Essen in alten Töpfen – verkohlte organische Reste
in frühneolithischen Tongefäßen aus Swifterbant, Niederlande (4300-4000 v. Chr.)

Nach der Untersuchung von Tongefäßen aus neolithischen Fundstellen bei Swifterbant (prov. Flevoland/NL) lassen sich zwei Untergruppen bilden. Es wird botanisch (mittels Rasterelektronenmikroskop) und chemisch (mittels Massenspektrometrie) analysiert, ob diese auch einen funktionalen Hintergrund haben – dies war der Fall: Die Gefäße der Gruppe 1 wurden für Mahlzeiten ohne Getreide (Emmer), jene der Gruppe 2 für Speisen mit Getreide verwendet. Es scheint, dass mit der Einführung von Getreide als Nahrungsmittel die traditionellen Gerichte im neuen Keramiktyp der Gruppe 1 zubereitet wurden, während die *nouvelle cuisine* dem alten Gefäßtyp der Gruppe 2 zugewiesen wurde. Diese Fallstudie zeigt, dass die Einführung von Getreide in die Ernährung der Swifterbant-Bevölkerung auch mit weiterführenden Handlungen verbunden war.

New food in old pots – charred organic residues
in Early Neolithic ceramic vessels from Swifterbant, the Netherlands (4300-4000 cal BC)

Our analyses of ceramics from the Neolithic sites near Swifterbant (prov. Flevoland/NL) suggest two distinctive subgroups. This study aims to determine whether these subgroups represent functional categories using botanical analysis (scanning electron microscope) and chemical residue analysis (direct temperature-resolved mass spectrometry). We conclude that there are two functional groups. Group 1 pots are used to cook meals without emmer, while group 2 pots are used to cook meals including emmer. It appears that with the introduction of emmer in the cooking process, traditional meals were transferred to a new type of pottery (group 1), while the *nouvelle cuisine* ended up in the traditional pots (group 2). This case study is strong evidence that the introduction of emmer in the diet of the Swifterbant people was an innovation embedded in meaningful action.

Anciens pots, nouvelle cuisine – restes organiques carbonisés
des céramiques du Néolithique ancien de Swifterbant, Pays-Bas (4300-4000 av. J.-C.)

L'étude des céramiques du site néolitihique de Swifterbant (prov. Flevoland/NL) a permis de constituer deux sous-groupes. Des études botaniques (microscopie électronique à balayage) et chimiques (spectrométrie de masse) ont permis de se poser la question de la fonctionnalité de ces sous-groupes. Il a pu être démontré que le groupe 1 correspond à des menus sans céréales (amidonnier), alors que le groupe 2 servait à cuisiner des céréales. L'introduction des céréales dans l'alimentation s'est traduite par un nouveau type de céramiques (groupe 1), alors que la »nouvelle cuisine« se faisait dans les vielles marmites (groupe 2). Cette étude de cas est un indice fort pour suggérer que l'introduction des céréales dans l'alimentation des habitants de Swifterbant était une innovation concertée. Ces indices montrent que l'étape de la néolithisation a été perçue comme signifiante. Traduction: L. Bernard

Schlüsselwörter / Keywords / Mots clés

Niederlande / Neolithikum / Keramik / Ernährung / Swifterbant / SEM-Analyse / DTMS-Analyse
The Netherlands / Neolithic / ceramics / nutrition / Swifterbant / SEM analysis / DTMS analysis
Pays-Bas / Néolithique / céramique / alimentation / Swifterbant / MEB / spectographie de masse

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