Context and contents

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ORIGINAL ARTICLE

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Context and contents: Distinguishing variation in archaeobotanical assemblage formation processes at Early Halaf Fistıklı Höyük, Turkey

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Abstract

Meaningful interpretation of archaeobotanical assemblages in the Near East often includes determination of whether dung fuel is the source of some or all of the recovered plant remains. In the years since Miller (Economy and Environment of Malyan, a Third Millennium B.C. Urban Center in Southern Iran. Ph.D. Dissertation, Department of Anthropology, University of Michigan, Ann Arbor, 1982; Paléorient 10:71–79, 1984) and Miller and Smart (J Ethnobiol 4:15–28, 1984) first identified archaeological plant remains from Malyan (Iran) as those of burned dung, subsequent archaeobotanical, experimental, and ethnographic research has been undertaken to test and expand her criteria for its recognition. A key criterion of Miller's was a high ratio of weed seeds to wood charcoal (or a low ratio of charcoal to weed seeds). When used together with other quantitative measures based on standardizing ratios, this measure can help to illuminate variability in the sources of the recovered carbonized plant remains and some of the taphonomic processes that contributed to the resulting assemblage. Using the Late Early Halaf dataset from Fistıklı Höyük, Turkey, as a case study, non-parametric statistical analysis was applied to eight such measures, including a new Fragmentation Index (*FI*), density measures (per litre of sediment) for charcoal, cereal grains, weed seeds, chaff, non-wood items, and cereal-type indeterminate non-wood items, and a relative density measure of charcoal to weed seeds. Each measure was calculated on the basis of 35 samples (n = 8,532). The results of this analysis indicate that these measures, when used in combination with Miller's weed seed to charcoal ratio, implemented here as the relative density of charcoal to weed seeds, can reveal recovery context-related variations in formation processes that help to clarify both the role of dung fuel in assemblage formation and to differentiate the remains of cereal processing from those of burned fuel.

Keywords Archaeobotany · Site formation processes · Dung · Statistical analysis · Crop processing · Fragmentation Index · Standardizing ratios

Introduction

Behavioural interpretation of archaeological plant remains requires disentanglement of the physical and social processes that shape archaeobotanical assemblages. Of particular importance in this regard is determining the source of the recovered plant materials (Hillman 1981; Minnis 1981; Miller and Smart 1984; Miksicek 1987; Pearsall 1988), their mode of carbonization (Minnis 1981; Miller and Smart 1984; Miksicek 1987; van der Veen 2007), and the depositional processes responsible for their interment and recovery (Minnis 1981; Miksicek 1987; Lennstrom and Hastorf 1995; Gallagher 2014). While seeds on archaeological sites have most often been interpreted as the remains of plants deliberately collected for use as food, medicines, fuel, or other purposes, or alternatively, as the remains of weeds unintentionally collected with harvested crops, Miller (1982, 1984) and Miller and Smart (1984) introduced a new idea for consideration in the early 1980s. Based on ethnographic observation, she proposed an innovative interpretation of the source of carbonized archaeobotanical material recovered from Malyan (Iran) as animal dung burned as fuel, and developed the first criteria used to distinguish dung-derived plant remains from those originating from other sources. Since then, dung has featured prominently in the

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interpretation of archaeobotanical remains from Near Eastern sites (Miller and Smart 1984; Miller 1996; Algaze et al. 1986; Charles 1998; Crawford 1999; Capper 2007; Deckers 2011; Miller and Marston 2012; Graham and Smith 2013), due to widespread evidence for its use as fuel across much of the Near East. As such, for Near Eastern sites where herd animals are abundant, a particular challenge is how to distinguish the residues of dung-burning from those resulting from other activities, such as crop processing (Fuller et al. 2014).

A key criterion of Miller's for the archaeobotanical identification of dung is a low ratio of charcoal to seeds, particularly small weed seeds (Miller 1984, 1996; Miller and Smart 1984). This criterion highlights Miller's emphasis on the utility of standardizing ratios in order to facilitate inter-sample comparison for samples with different volumes or for which the volume is unknown (Miller 1988). The use of standardizing ratios has since been widely applied, with van der Veen (1992, 2007; van der Veen and Jones 2006) arguing for their particular utility for evaluating assemblage formation processes. Miller also advocated more rigorous attention to "deposit-by-deposit reporting of context and content" (Miller 1996, p 525) and consideration of recovery context in the interpretation of archaeobotanical assemblages.

This study builds on these three methodological emphases of Miller's research—the identification of animal dung as a source of plant remains, the use of standardizing ratios, and attention to context—and integrates them into a combined contextual and compositional approach in order to assess the contribution of dung to the Late Early Halaf archaeobotanical assemblage from Fıstıklı Höyük in southeastern Turkey (Fig. 1), dated to ca. 6000–5700 cal BC (Bernbeck et al. 2003). Located on the eastern edge of the Euphrates floodplain, the site of Fıstıklı Höyük was excavated in 1999 and 2000 under the direction of Susan Pollock and Reinhard Bernbeck as part of a salvage project (TAÇDAM), directed by Numan Tuna (Middle East Technical University in Ankara), related to construction of the Carchemish Dam. Fıstıklı is a small 0.5 ha Early Halaf settlement situated on a low terrace just south of the great bend of the Euphrates (Bernbeck et al. 2003).

Several lines of evidence suggest that spent dung fuel is likely to have contributed to the Fıstıklı Late Early Halaf archaeobotanical assemblage. Specifically, wood charcoal and cereal grains are low in abundance (Miller 1984; Miller and Smart 1984; Miller and Marston 2012), chaff dominates the assemblage (Charles 1998; Valamoti and Charles 2005), and the assemblage is heavily fragmented (Spengler et al. 2013). In addition, the faunal assemblage for this period is dominated by domesticated sheep and goats (Bernbeck et al. 2003), which would have produced a readily available supply of dung. However, routine daily activities, such as crop and food processing, are also likely to have contributed to the assemblage (Charles 1998; Fuller et al. 2014). Because the Fıstıklı archaeobotanical assemblage is characterized by low charcoal densities, few cereal grains, and high quantities of cereal chaff, it appears qualitatively to meet several criteria for recognition as dung on the one hand, and cereal processing on the other. As such, it provides an excellent case study for investigating potential quantitative methods to distinguish different sources of charred plant material, specifically with reference to spent dung fuel vs. other activities, such as crop processing and food preparation.

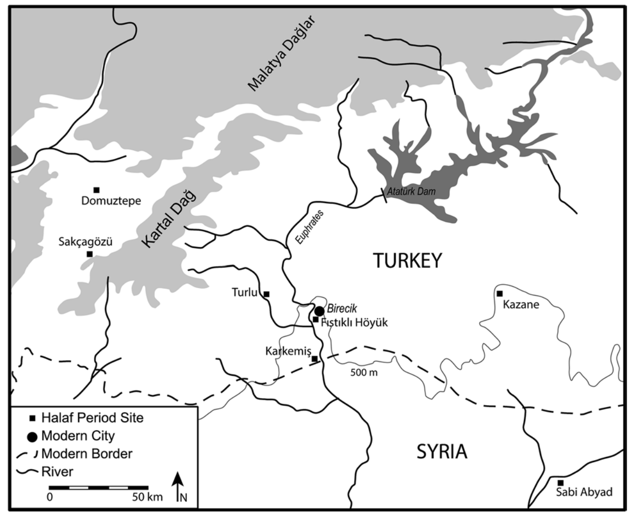

Fig. 1 Location of Fıstıklı Höyük in relation to other Halaf sites in the region. Prepared by John Wallrodt, after Bernbeck et al. (2003)

In order to address these issues, non-parametric statistical analysis was conducted for eight standardizing ratios for data from 35 macrobotanical samples (n = 8,532 non-wood items) derived from Fıstıklı Höyük IIIa–c deposits identified during excavation as hearth, exterior surface, interior surface, midden, and midden-pit contexts. The use of descriptive statistics to assess compositional patterning for these context groups facilitates recognition of the plant sources and site formation processes that have shaped the assemblage and points toward a low contribution of dung fuel as only a secondary or background source of plant remains at Fıstıklı. The standardizing ratios examined in this analysis are density values for charcoal, non-wood items, cereal grains, weed seeds, chaff, and indeterminate non-wood fragments that are consistent with cereal grain endosperm, the relative density of charcoal to weed seeds, and a new measure, the Fragmentation Index (*FI*). Significantly, this approach bridges the divide between what Fuller et al. (2014, p 175) term "the tyranny of context" and the "power of content." Although this study focused on variation between recovery context types, these measures can—and should—also be applied for comparison of samples within a specific context type or single deposit in order to assess variation in sample

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composition and preservation within specific context types and discrete depositional contexts, as will be undertaken in a follow-up study.

Background

Archaeobotanical identification of dung

Both modern and ancient use of animal dung as fuel is widely attested in the Near East and many other regions. Since Naomi Miller's ground-breaking interpretation of the archaeobotanical assemblage from Malyan as the remains of burned dung, scholars have routinely identified it in other assemblages. Although this is particularly true for the Near East and south-eastern Europe (Miller 1984, 1996; Miller and Smart 1984; Charles 1998; Valamoti 2004; Miller and Marston 2012; Graham and Smith 2013), dung has also been identified in assemblages from Central Asia (Spengler et al. 2013; Spengler 2018), North America (Miller and Smart 1984), South America (Pearsall 1988), and south Asia (Reddy 1999).

The initial criteria for identifying dung-derived plant remains, as first articulated by Miller (1982, 1984; Miller and Smart 1984), are: (1) location of the site in an area lacking abundant wood; (2) the presence of dung-producing animals; (3) burned dung fragments or seeds of plants potentially or likely to have been consumed by animals (i.e. those without other known economic uses); and (4) "the archaeological context of the samples suggests a primary hearth deposit or secondary dumping of hearth contents" (Miller and Smart 1984, p 20). With respect to Miller's criteria 1 and 3, a high ratio of seeds to charcoal (or a low ratio of charcoal to non-wood), by weight, is often used as an indicator of the presence of dung-derived material (Miller 1984; Miller and Smart 1984; Miller and Marston 2012; Spengler et al. 2013).

Following closely on Miller's earliest discussions of dung, Charles (1998) developed several useful additions to these criteria, noting that Miller's first and second criteria are more an explanation for why dung fuel would be used, rather than direct evidence for dung fuel as a source of plant remains. Charles' (1998) additions, based on ethnoarchaeological studies of crop processing together with the biological and ecological characteristics of wild plants, were proposed in order to increase the reliability of archaeobotanical dung identification. In particular, he emphasized the need to consider three additional attributes of assemblages: (1) seed size and weight, as correlates of different stages of crop processing (Hillman 1981; Jones 1987); (2) the seasonal availability of the recovered wild taxa relative to those of the crops themselves, as an indicator of whether or not they could have been collected as weeds of crops (Hillman 1991); and (3) the relative frequency of crop seeds and chaff. Using discriminant analysis, Charles (1998) compared descriptive statistics for the stages of crop processing, based on seed size, weight, and plant parts, recorded for modern crop processing on Amorgos (Jones 1987) with archaeobotanical data for Abu Salabikh (Iraq) and Tel Brak (Syria). The results demonstrated that crop processing by-products were the dominant source of plant material in the Tell Brak assemblage, whereas dung contributed more to the Abu Salabikh assemblage (Charles 1998).

More recently, these criteria have been tested, revised, and expanded upon through strategies such as experimental carbonization and feeding in order to document the morphological and compositional transformations that plant remains undergo during the processes of digestion and subsequent burning (Valamoti and Charles 2005; Spengler et al. 2013; Valamoti 2013; Wallace and Charles 2013). Results from such studies provide strong evidence for the addition of three more criteria to Miller's original list: (1) a relative absence of cereal grains, which typically do not survive digestion in identifiable form (Valamoti and Charles 2005; Valamoti 2013; Wallace and Charles 2013); (2) vertically-split glume bases (Valamoti and Charles 2005; Valamoti 2013); and (3) roughened glume base surfaces that are observable both macroscopically and with scanning electron microscopy (Valamoti 2013). In their analysis of material from Begash (Kazakhstan), Spengler et al. (2013) cite a high degree of fragmentation and unidentifiable non-wood fragments as an additional criterion for recognition of dung-derived plant remains, but note the challenge of quantifying the degree of fragmentation.

Other sources of charred plant remains

Even when it can be demonstrated that dung contributes to an archaeobotanical assemblage, it should not be assumed to be their only source (Charles 1998; Valamoti 2004; Fuller et al. 2014). Instead, "certain recurrent and cross-cultural practices, such as plant food processing, are likely to be the more quantitatively significant" (Fuller et al. 2014, p 187). Fuller et al. (2014) further suggest that when present, dung-derived material may "just add noise to the evidence of arable weed-chaff assemblages" (p 189). In support of this argument, they cite Reddy's (1999) ethnoarchaeological studies in Northern India, where she documented a greater contribution of food processing waste than dung in material collected from household hearths where dung-fuel was used (Fuller et al. 2014, p 189). Other sources of carbonized plant remains include plants used as medicines, in rituals, or as decorative elements, which may become carbonized through accidental or deliberate burning. Thus, it is essential for researchers working in areas where dung is commonly

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used as fuel to be able to distinguish different contributions to archaeobotanical assemblages.

Non-dung fuel sources

In addition to animal dung, both wood and waste products from crop and food processing are often used as fuel. While charcoal is not abundant at Fistıklı, it is notable that in arid settings, chaff and straw—in addition to dung—are highly valued in their own right as a source of fuel and an economic commodity (van der Veen 1999). Straw, represented by cereal culm fragments, is rare at Fistıklı (n = 8). In contrast, glume wheat chaff (spikelet forks and glume bases) is dominant in the assemblage. Chaff elements are produced at three points in the production process: winnowing, coarse-sieving, and finally, pounding and fine-sieving to remove the tough outer glumes from the grains (Hillman 1981; Jones 1987). Glume bases often become charred as "the result of their use as a 'casual fuel'" (van der Veen 2007, p 978), an ad hoc use of available crop processing by-products. However, as noted above, glume bases can also become charred during the parching of glume wheats to facilitate removal of their tough outer glumes.

Cereal crop processing

Building on Hillman's (1981, 1984) foundational ethnoarchaeological documentation of the kinds of archaeobotanical assemblages resulting from different stages in cereal crop processing, particularly with reference to the relative proportions of chaff, weed seeds, grain, and straw, other scholars have expanded on these principles. Jones (1984, 1987) considered weed seed size and weight as key variables for discriminating different stages of crop processing, an approach followed by Charles (1998) and Graham and Smith (2013). For hulled wheat and barley, the only cereals present at Fistıklı, the primary stages of processing (following Stevens 2003) are: (1) threshing, which breaks up inflorescences and culms; (2) raking; (3) initial winnowing, which removes light chaff and weed seeds; (4) coarse sieving to separate out intact inflorescence parts in need of further threshing; (5) fine sieving to remove small chaff items such as awns and small weed seeds; (6) pounding to separate spikelet forks, lemmas, and paleas from grains; (7) re-winnowing to separate grains from chaff by weight differences; (8) medium-coarse sieving to recover spikelet forks and unbroken spikelets in need of further pounding; (9) second fine-sieving to remove small grains, weed seeds, and chaff items (glume bases and awns). Materials from these stages of processing may become charred either through their casual or regular use as fuel (van der Veen 1992, 2007), disposal into hearths as waste-products, or through the parching of threshed spikelets to make the outer glumes easier to remove (Hillman 1984).

Foods and food processing

Foods that require heat in their processing and are therefore more subject to accidental burning are those most likely to be represented in carbonized plant assemblages (Minnis 1981; Miksicek 1987; van der Veen 2007; Gallagher 2014). These kinds of activities, such as baking, boiling, parching, and roasting, constitute a key domain of daily routine activities on archaeological sites. As such, these behaviours are widely accepted as significant contributors to the charred archaeobotanical record (Dennell 1972, 1974, 1976; Hillman 1981; van der Veen 2007; Fuller et al. 2014; Gallagher 2014).

Identifying sources

The interpretation of assemblages that result from targeted sampling focused on collection of samples from specific context types, such as hearths, is often based on an unwarranted assumption that the contents of the feature represent behaviours associated with it. However, as demonstrated by Lennstrom and Hastorf (1995) in their comparison of sample composition between features and adjacent or overlying deposits, feature fills often represent post-use processes of deposition. While such an approach is possible when a spatially intensive sampling strategy was adopted (e.g. Hansen and Allen 2011; Allen and Forste 2019), this was not the case for Fistıklı, where the excavators adopted a targeted sampling strategy. As such, samples from deposits adjacent to the contexts selected for sampling are inconsistently available for compositional comparison, and an alternative approach is needed in order to determine whether sample composition reflects recovery context or post-depositional fill. If the deposits from different context groups have undergone variable cultural and natural taphonomic processes related to their use (whether primary or later), rather than a palimpsest of post-depositional mixing and redeposition, they should show discernible compositional differences, as detected through the non-parametric statistical comparison of the eight quantitative indexes.

Fistıklı Höyük III assemblage overview

The 35 Late Early Halaf (Fistıklı IIIa–c) samples used for this analysis were recovered from 10 different locations representing five different context types that were identified during excavation (Table 1). These consist of interior surfaces (n = 3), exterior surfaces (n = 15), middens (n = 8), "midden-pits" (pits associated with middens) (n = 5) and hearths (n = 4). Due to the small quantity of samples available for

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Table 1 Number of flotation samples included for analysis from each context type

Context type	Interior surface (int surf)	Exterior surface (ext surf)	Midden	Pit associated with midden (M-Pit)	Hearth
No. of samples	3	15	8	5	4

For exterior surfaces, middens, and midden-pits, the quantity of samples is the same as the number of observations for each group in the Mann–Whitney U analysis

interior surfaces and hearths, the results for these contexts are less meaningful than those for context types with more samples (exterior surfaces, middens, and midden-pits).

Three striking patterns are evident in the Fistıklı IIIa–c (Late Early Halaf) assemblage: an overwhelming dominance of cereal chaff in most samples, low densities of wood charcoal, and a low frequency of weed seeds. While these patterns correspond to two commonly used criteria for the archaeobotanical recognition of dung—the regular occurrence of chaff (Miller 1984, 1996; Miller and Smart 1984; Graham and Smith 2013) and the paucity of charcoal (Miller 1984, 1996; Miller and Smart 1984), and one recently suggested criterion—marked fragmentation (Spengler et al. 2013)—the low relative frequency of weed seeds as compared with other plant remains is inconsistent with the interpretation of the recovered material as the remains of burned dung.

A narrow suite of crops, dominated by *Triticum monococcum* (einkorn), was identified in the IIIa–c assemblage from Fistıklı. Other crops include *Hordeum vulgare* var. *distichum* (two-row barley), *T. dicoccum* (emmer), *Lens culinaris* (lentil), and *Linum usitatissimum* (flax), with the latter three occurring only rarely. Identifiable whole cereal grains are rare, while distorted and cereal grains that are not identifiable to genus and show a characteristic "spongy", or vesicular, structure, are more common. In contrast to the low frequency of cereal grains, chaff from hulled wheat (spikelet forks and glume bases) occurs in nearly all flotation samples. The overwhelming majority of these are identifiable as *T. monococcum* or *T. monococcum/dicoccum*-type glume bases, with significantly fewer intact spikelet forks, all of which are *T. monococcum* or *T.* sp.

In addition to the recovered cultivars, several non-domesticated taxa were also recovered. Some of which, such as *Chenopodium* sp. and *Echium vulgare*, have also been documented as regular components of dung-derived assemblages (Miller 1984, 1996; Miller and Smart 1984; Spengler et al. 2013; Spengler 2018). At Fistıklı, however, nearly all of the recovered *Chenopodium* sp. and *E. vulgare* specimens are not carbonized, and those tested by sectioning contain intact endosperm, indicating their modern status. As such, these were most likely deposited as intrusive modern seed rain incorporated into the deposits (Minnis 1981; Gallagher 2014), an inference supported by the shallow depth of the deposits, which was generally less than 1.5–2 m (Bernbeck et al. 2003). Although it is possible for some seeds to remain uncarbonized when incorporated into animal dung that was burned as fuel, it seems highly unlikely that one or two taxa would consistently be the only ones for which this is the case. Given the high likelihood that the recovered uncarbonized wild seeds are modern intrusions, only carbonized specimens were considered in this analysis.

In addition to the occasional carbonized specimens of *Chenopodium* sp. and *Echium* sp., other taxa often associated with cereal cultivation were also recovered. These include *Aegilops* cf. *speltoides*, represented by both seeds and spike bases, *Hordeum murinum, H. spontaneum, Lolium* sp., *L. perenne, L. temulentum, Galium* sp., cf. *Euphorbia* sp., *E. helioscopia, Cerastium* sp., *Silene* sp., *Thymelaea* sp., cf. *Portulacca* sp., cf. *Astragalus* sp., and *Medicago* sp. were also recovered. Despite their apparent taxonomic diversity, however, wild plants are infrequent in the majority of samples. Given the segetal and/or ruderal status of the recovered taxa, these are considered here as potential field weeds or taxa with "weedy" growth habits that are often consumed by ruminants, and thus referred to as "weed seeds" for consistency with Miller's use of weed seeds as an index for the recognition of dung-derived plant remains.

Methods

Sampling and recovery

Archaeobotanical sampling on-site (Fig. 2), coordinated by the project directors, consisted of targeted recovery of flotation samples from areas that appeared to be either ashy or rich in organic remains. Dry sediment volumes were recorded for each sample prior to flotation. Flotation samples were processed using a SMAP-style machine fitted with a 2 mm mesh for heavy fraction and a 0.15 mm light fraction mesh in order to maximize recovery of chaff material and small weed seeds. The combined light and heavy fraction from these samples was sent to the United States for analysis in the laboratory of the Department of Archaeology at Boston University and, subsequently, the Department of Anthropology at the University of Cincinnati.

Sorting and identification

Prior to sorting, geological sieves were used to screen all samples into four size fractions (> 2 mm, 1–2 mm, 0.5–1.0 mm, and < 0.5 mm) to facilitate sorting. In order

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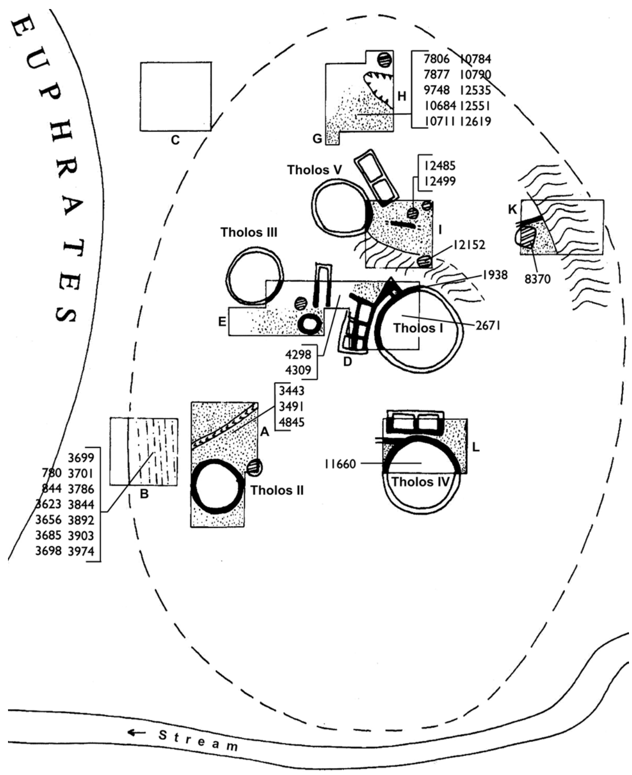

Fig. 2 Location of macrobotanical samples for Fistıklı Höyük IIIa–IIIc and associated structures. Prepared by John Wallrodt

to reduce size biases in preservation and provide a more accurate representation of small weed seeds and chaff elements in this analysis, all fractions were completely sorted. All recovered seeds and seed fragments from all size fractions were included in this analysis. Taxonomic and anatomical identification of non-wood remains was undertaken with the use of low-level stereomicroscopy (up to 60×) and comparison of ancient material to modern reference specimens housed in the Mediterranean Ecosystem Dynamics and Archaeology (MEDArch) Laboratory at the University of Cincinnati, standard seed atlases (e.g. Martin and Barkley 1961; Cappers et al. 2009; Neef et al. 2012) and previously published assemblages from the region (e.g. van Zeist 1980; van Zeist and Bakker-Heeres 1986; van Zeist and Waterbolk-van Rooijen 1989, 1996).

Quantitative analysis

Following Naomi Miller's advocacy for the use of standardizing ratios for inter-sample (Miller 1988) comparison, expanded upon by van der Veen (1992, 1999, 2007), eight measures based on standardizing ratios were calculated for the dataset. These include both density measures for discrete combinations of various plant types and parts (e.g. wood charcoal, weed seeds, cereal chaff, cereal grains, non-wood items, non-wood indet. cereal-type items), the relative density of charcoal to weed seeds, and a new measure, the Fragmentation Index (*FI*), as described below (Table 2).

Absolute counts

For the absolute counts of cereal grains used in the density calculations and the Fragmentation Index, items were counted as "whole" on the basis of the presence of unique parts, such as the hilum for legumes and the embryo for grass caryopses, as advocated by Jones (1990). Seed parts lacking these features were characterized as fragmentary. For density calculations only, these absolute counts based on unique anatomical features for the recognition of wholes were subsequently standardized to single grains using conversion factors of three caryopsis fragments per whole cereal grain (3:1), which accords well with the MNI results for einkorn obtained by Antolín and Buxó (2011) through the application of their novel method based on more precise characterization of fragment type. As noted by Antolín and Buxó, fragmentary remains must be taken into account when interpreting archaeobotanical assemblages. Although their method provides a more precise method for converting fragments to wholes, the use of a factor of 3:1 for cereal grains provides a more rapid means of taking fragments into account when characterizing assemblage composition, and is warranted in the case of Fistikli, where einkorn is the dominant cereal.

For chaff (glume bases and spikelet forks), counts of glume bases were standardized to grains using a factor of 2 glume bases per grain (2:1). This conversion factor is justified by the dominance of einkorn, for which this ratio is standard. For weed seeds, a conversion factor of three fragments per whole seed was used (3:1) for expediency, but could be improved by more explicit consideration of individual taxa. For each density measure, the raw (non-wood items, "non-wood, Cereal endosperm type") or converted (cereal grains, weed seeds, chaff) count acted as the numerator, and the sample volume as the denominator.

Density calculations

Charcoal density was calculated on the basis of the > 2 mm charcoal weight (g/L), while other density measures were calculated on the basis of the converted absolute counts for each category of material in the sample (#/L). These include cereal grains, cereal chaff, carbonized weed seeds, charred non-wood items, and non-wood charred material that is consistent with cereal/grass endosperm (hereafter "non-wood, Cereal endosperm type").

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Table 2 Raw counts and calculated standardizing measures for Fistıklı IIIa–c

Sample	Cntxt Grp	Vol	>2 ch wt	CerGr Ct	CWdSd Ct	Chaff Ct	NWIndCT Ct	Total CNW	CNW Wh	CNW Wh_GlBs	Cer Frgs	Ch Dens	CerGr Dens	WdSd Dens	Chaff Dens	NW Dens	NWInd CTDens	FI	CerGr: Chaff	CerGr: WdSd	Charc: WdSd	Charc: NWCerInd	NWCerInd: CerGr	CerGr: NWIndCer
E10684	Ext Surf	8	0.57	26.33	12	61	76	280	39	127	52	0.07	3.29	1.5	7.63	35	9.5	0.14	0.431	2.193	0.047	0.007	2.89	0.346
E10711	Ext Surf	5	0.15	10.33	2	17	52	125	8	44	28	0.03	2.07	0.4	3.4	25	10.4	0.06	0.609	5.175	0.075	0.003	5.02	0.199
E10784	Ext Surf	8	0.33	59	10	62	0	305	63	167	161	0.04	7.38	1.25	7.75	38.13	0	0.21	0.952	5.904	0.032		0.00	
E10790	Ext Surf	12	0.16	12.33	10.33	43.5	15	156	20	89	28	0.01	1.03	0.86	3.63	13	1.25	0.13	0.284	1.198	0.012	0.008	1.21	0.824
E12535	Ext Surf	10	0.01	6	24.33	126	142	440	30	258	15	0	0.6	2.43	12.6	44	14.2	0.07	0.048	0.247	0.000	0.000	23.67	0.042
E12551	Ext Surf	4	0.04	2	7.66	64.5	42	175	27	112	0	0.01	0.5	1.92	16.13	43.75	10.5	0.15	0.031	0.260	0.005	0.001	21.00	0.048
E12619	Ext Surf	7	0.3	83	26.66	134	7	475	92	270	189	0.04	11.86	3.81	19.14	67.86	1	0.19	0.620	3.113	0.010	0.040	0.08	11.860
E3443	Ext Surf	3	0.02	0	2.33	2.5	13	21	3	6	0	0.01	0	0.78	0.83	7	4.33	0.14	0.000	0.000	0.013	0.002		0.000
E3491	Ext Surf	5	0.03	3.33	1.66	4	17	32	5	4	3	0.01	0.67	0.33	0.8	6.4	3.4	0.16	0.838	2.030	0.030	0.003	5.07	0.197
E4298	Ext Surf	9	0.59	0	3.33	13.5	31	68	6	21	10	0.07	0	0.37	1.5	7.56	3.44	0.09	0.000	0.000	0.189	0.020		0.000
E4309	Ext Surf	14	0.24	2	13	16	0	60	11	37	0	0.02	0.14	0.93	1.14	4.29	0	0.18	0.123	0.151	0.022		0.00	
E4845	Ext Surf	10	0.13	1.33	9.66	15	25	73	11	34	1	0.01	0.13	0.97	1.5	7.3	2.5	0.15	0.087	0.134	0.010	0.004	19.23	0.052
E7806	Ext Surf	5	0.24	4.33	1.33	6.5	52	78	4	17	4	0.05	0.87	0.27	1.3	15.6	10.4	0.05	0.669	3.222	0.185	0.005	11.95	0.084
E7877	Ext Surf	7	0.15	7	14	21	207	297	15	32	18	0.02	1	2	3	42.43	29.57	0.05	0.333	0.500	0.010	0.001	29.57	0.034
E9748	Ext Surf	4	0.03	5.66	17.66	13.5	221	287	16	35	19	0.01	1.42	4.42	3.38	71.75	55.25	0.06	0.420	0.321	0.002	0.000	38.91	0.026
E9748	Ext Surf	4	0.03	5.66	17.66	13.5	221	287	16	35	19	0.01	1.42	4.42	3.38	71.75	55.25	0.06	0.420	0.321	0.002	0.000	38.91	0.026
H12152	Hearth	10	0.06	9	22	43.5	10	186	17	96	17	0.01	0.9	2.2	4.35	18.6	1	0.09	0.207	0.409	0.005	0.010	1.11	0.900
H12485	Hearth	17	0.35	18.33	25	56	57	285	33	135	40	0.02	1.08	1.47	3.29	16.76	3.35	0.12	0.328	0.735	0.014	0.006	3.10	0.322
H12499	Hearth	18	0.29	15.66	26.33	82.5	67	320	44	169	44	0.02	0.87	1.46	4.58	17.78	3.72	0.14	0.190	0.596	0.014	0.005	4.28	0.234
H8370	Hearth	6	0.01	2	23	42	0	131	22	90	3	0	0.33	3.83	7	21.83	0	0.17	0.047	0.086	0.000		0.00	
I11660	Int Surf	12	0	0.33	1	6	29	48	2	51	1	0	0.03	0.08	0.5	4	2.42	0.04	0.060	0.375	0.000	0.000	80.67	0.012
I1938	Int Surf	6	0	3	2.66	0.5	0	18	3	4	6	0	0.5	0.44	0.08	3	0	0.17	6.250	1.136	0.000		0.00	
I2671	Int Surf	4	0	0	3	7.5	0	31	3	16	0	0	0	0.75	1.88	7.75	0	0.1	0.000	0.000	0.000			
M3623	Midden	8	1.2	10	13.66	86.5	320	531	31	178	18	0.15	1.25	1.71	10.81	66.38	40	0.06	0.116	0.731	0.088	0.004	32.00	0.031
M3656	Midden	8	0.93	0	9.66	15	47	102	4	22	0	0.12	0	1.21	1.88	12.75	5.88	0.04	0.000	0.000	0.099	0.020		0.000
M3698	Midden	1	0.7	2.33	0	7.5	21	36	6	7	1	0.7	2.33	0	7.5	36	21	0.17	0.311			0.033	9.01	0.111
M3699	Midden	9	2.42	14	12	0	194	231	22	22	6	0.27	1.56	1.33	0	25.67	21.56	0.1		1.173	0.203	0.013	13.82	0.072
M3701	Midden	6	0.21	1	11.66	12.5	53	114	15	49	0	0.04	0.17	1.94	2.08	19	8.83	0.13	0.082	0.088	0.021	0.005	51.94	0.019
M3786	Midden	7	0.18	0	2	7	74	92	4	15	0	0.03	0	0.29	1	13.14	10.57	0.04	0.000	0.000	0.103	0.003		0.000
M3974	Midden	8	1.02	3	6	9.5	141	179	4	23	9	0.13	0.38	0.75	1.19	22.38	17.63	0.02	0.319	0.507	0.173	0.007	46.39	0.022
M780	Midden	3	0.3	6	5.33	28	152	222	15	36	9	0.1	2	1.78	9.33	74	50.67	0.07	0.214	1.124	0.056	0.002	25.34	0.039
MP3685	M-Pit	8	2.04	14	41	183	930	1467	117	342	6	0.26	1.75	5.13	22.88	183.38	116.25	0.08	0.076	0.341	0.051	0.002	66.43	0.015
MP3844	M-Pit	6	0.41	6	10	8	235	284	9	21	12	0.07	1	1.67	1.33	47.33	39.17	0.03	0.752	0.599	0.042	0.002	39.17	0.026
MP3892	M-Pit	4	0.25	37.33	16.66	95	665	950	53	186	79	0.06	9.33	4.17	23.75	237.5	166.25	0.06	0.393	2.237	0.014	0.000	17.82	0.056
MP3903	M-Pit	7	0.62	2.66	11.33	19.5	198	270	8	31	5	0.09	0.38	1.62	2.79	38.57	28.29	0.03	0.136	0.235	0.056	0.003	74.45	0.013
MP844	M-Pit	8	0.2	7.33	3	19	174	235	33	67	19	0.03	0.92	0.38	2.38	29.38	21.75	0.14	0.387	2.421	0.079	0.001	23.64	0.042

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Fragmentation Index

The Fragmentation Index (*FI*) was developed for this study in order to facilitate recognition of variation in the degree of breakage within the assemblage, given that high fragmentation has been linked with dung-derived assemblages (Spengler et al. 2013). Significantly, the *FI* addresses the need for a quantitative method to characterize fragmentation, as previously noted by Antolín and Buxó (2011) and by Spengler et al. (2013) in their discussion of plant remains from Begash (Kazakhstan). *FI* is calculated by creating a ratio with the total number of whole carbonized non-wood (NW) items, as recognized on the basis of unique anatomical parts such as cereal embryos (Jones 1990), as the numerator and the total number of fragmentary carbonized non-wood items as the denominator (Total#NWwhole/Total#NWfrag). As such, larger values (i.e. those closer to 1) reflect a lower degree of fragmentation (i.e. a relative equivalence of complete to fragmentary remains) whereas smaller values, such as 0.01, reflect greater fragmentation (i.e. a lower proportion of complete to fragmentary remains). Because the *FI* is volume-independent, it allows for recognition of variable fragmentation even when sample sizes differ considerably.

Context grouping and statistical analysis

In order to assess whether or not: (1) variation within the assemblage is related to contextual differences, and (2) discrete contexts represent varied depositional patterns, density and *FI* values for all samples were grouped by context for further examination with non-parametric rank-based statistical tests. The Kruskal–Wallis test was employed to compare differences in the distribution of median values for FI and all density measures across context groups, while the Mann–Whitney U test was used for pairwise comparison between context types of the distribution of values for specific measures. For both tests, the significance level (alpha) was set prior to analysis at $p < 0.05$.

Results

Whereas the assemblage appears to be relatively homogeneous when considered in terms of the relative frequency of cereal grains, charred weed seeds, and cereal chaff (Fig. 3), non-parametric statistical analysis reveals greater variation in the assemblage. Specifically, the distribution of *FI* values and density measures for charcoal, weed seeds, non-wood items, and especially "non-wood indeterminate, cereal endosperm type" reveal patterning which, in some cases, reflects variation in the pre- and post-depositional assemblage formation processes specific to different contexts of recovery.

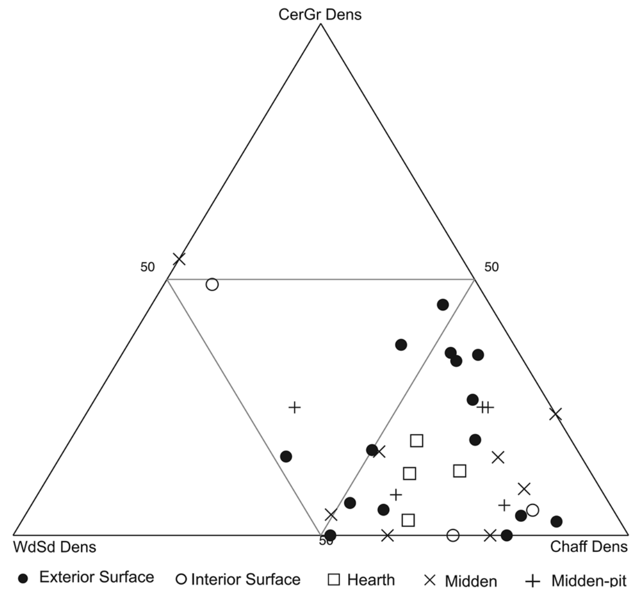

Fig. 3 Ternary plot showing contextual comparison of flotation sample composition for midden, hearth, and interior/exterior surface contexts at Fıstıklı Höyük (IIIa/b), calculated on the basis of cereal crop seed, cereal chaff (normalized to 1-grain equivalencies), and carbonized weed seed densities

Kruskal–Wallis test results

Analysis of density values and *FI* for the five broad context types (ext surf, hearth, int surf, midden, and M-Pits, Figs. 4, 5, 6, 7, 8) with the non-parametric Kruskal–Wallis test (Table 3) revealed statistically significant differences between context types for ChDens ($p < 0.001$), WdSdDens ($p = 0.024$), NWDens ($p = 0.005$), and NWIndCerDens ($p = < 0.001$) values. In other words, the median values for ChDens, WdSdDens, NWDens, and NWIndCerDens show significant variation across context types when all context groups are considered. However, the Kruskal–Wallis test does not indicate which context group is stochastically dominant for each variable, only that statistically significant non-random variation is present.

Fragmentation Index

As shown in Figs. 4, 5, 6, 7 and 8, the *FI* values for the IIIa–IIIc samples considered here are typically low, with only a few samples having *FI* values above 0.4. For all context types, the median *FI* ranges from 0.06 to 0.14, indicating relatively high fragmentation in most samples for all context types. Samples from exterior surface and hearth contexts show the highest medians (0.14 and 0.13, respectively), indicating lower fragmentation than other context types.

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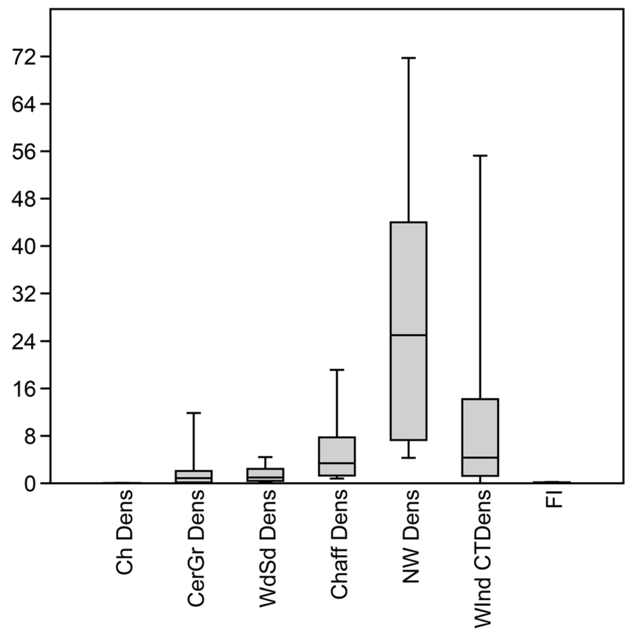

Fig. 4 Box and whisker plots for charcoal density (ChDens), weed seed density (WdSdDens), non-wood density (NWDens), non-wood indet. Cereal endosperm type (NWIndCerDens) and Fragmentation Index (*FI*), values for exterior surface samples (n = 15)

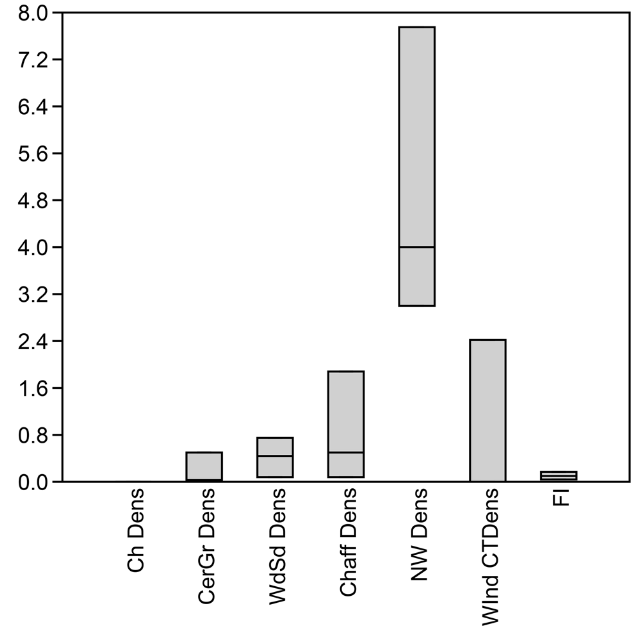

Fig. 6 Box and whisker plots for charcoal density (ChDens), weed seed density (WdSdDens), non-wood density (NWDens), non-wood indet. Cereal endosperm type (NWIndCerDens) and Fragmentation Index (*FI*), values for interior surface samples (n = 3)

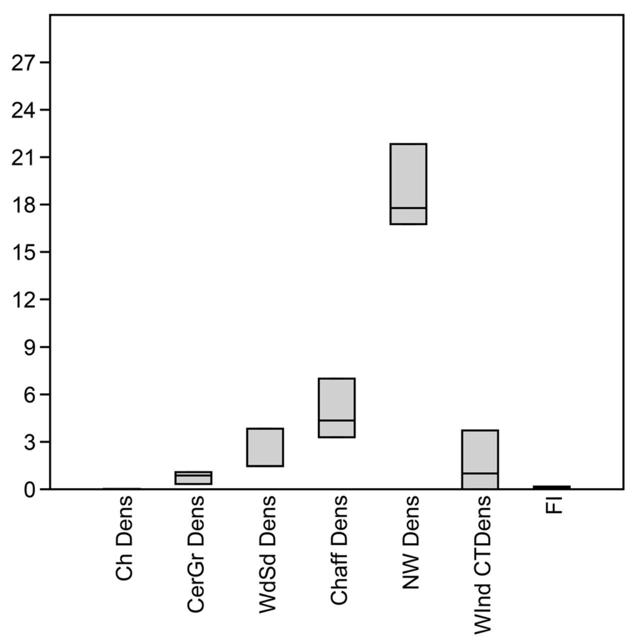

Fig. 5 Box and whisker plots for charcoal density (ChDens), weed seed density (WdSdDens), non-wood density (NWDens), non-wood indet. Cereal endosperm type (NWIndCerDens) and Fragmentation Index (*FI*), values for Hearth samples (n = 4)

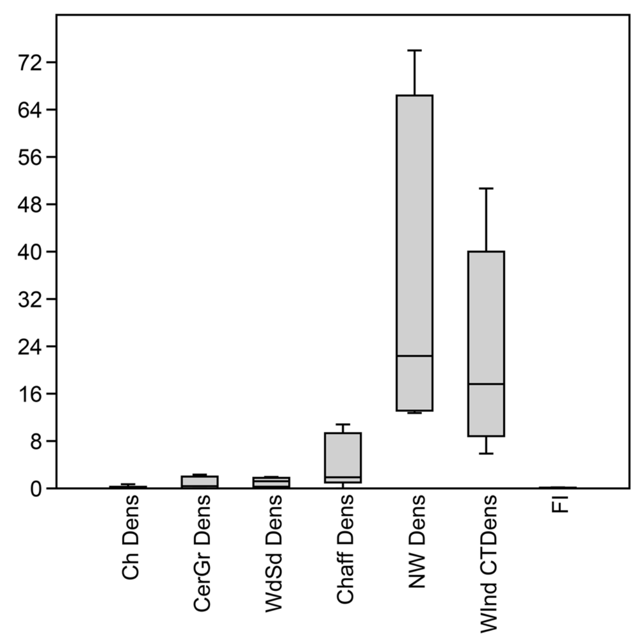

Fig. 7 Box and whisker plots for charcoal density (ChDens), weed seed density (WdSdDens), non-wood density (NWDens), non-wood indet. Cereal endosperm type (NWIndCerDens) and Fragmentation Index (*FI*), values for midden samples (n = 8)

However, the Kruskal–Wallis test results for *FI* ($p = 0.100$) indicate that there is not a statistically significant difference in the median values of *FI* (significance level at $p < 0.05$) when all context groups are considered (Table 3).

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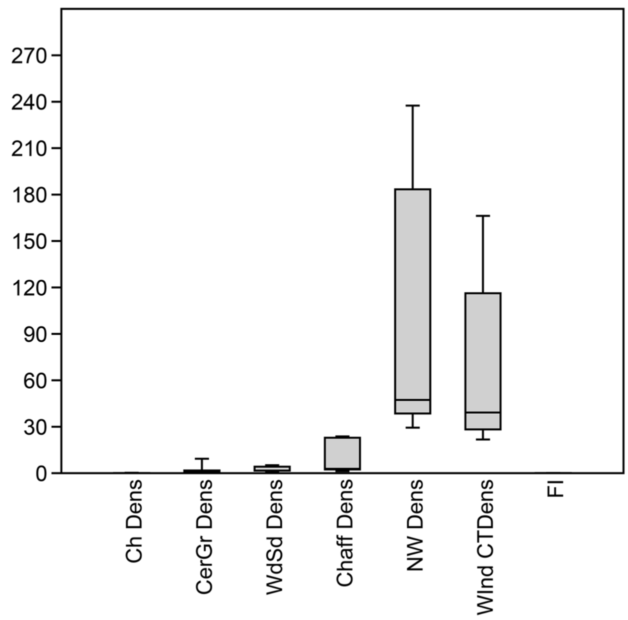

Fig. 8 Box and whisker plots for charcoal density (ChDens), weed seed density (WdSdDens), non-wood density (NWDens), non-wood indet. Cereal endosperm type (NWIndCerDens) and Fragmentation Index (*FI*), values for midden-pit samples (n = 5)

Charcoal density

Charcoal density values (Figs. 4, 5, 6, 7, 8) are low for nearly all samples, with a range from 0.00 to 0.70 g/L, with higher median values and wider distributions of values for midden and midden-pit contexts as compared with other context types. Analysis of charcoal density values with the Kruskal–Wallis test (Table 3) produced a p value of < 0.001, indicating statistically significant variation among charcoal density values for samples from the different context types.

Cereal grain density

Most samples have cereal grain density values that are below three cereal grains per litre (Figs. 4, 5, 6, 7, 8), with medians ranging from 0.03 (Interior Surfaces) to 1.75 (Midden-Pits). The Kruskal–Wallis test (Table 3) produced a p value of 0.214, indicating a lack of statistically significant support for context-related variation in cereal grain density values.

Weed seed density

Weed seeds show density values (Figs. 4, 5, 6, 7, 8) of fewer than five seeds per litre for all context types, with median values ranging from 0.44 (Interior Surfaces) to 1.84 (Hearths). Analysis of weed seed density values for all context groups with the Kruskal–Wallis test (Table 3) produced a p value of 0.0024, indicating statistically significant variation in the median values for the five context groups and a linkage between context type and weed seed density.

Chaff density

Chaff density values range from 0.00 to 23.75 chaff items per litre (Figs. 4, 5, 6, 7, 8) and show similar medians across context types. The Kruskal–Wallis test (Table 3) returned a p value of 0.084, indicating a lack of significant variation in chaff density medians for different recovery contexts.

Non-wood item density

Density values for non-wood items (NWDens), a category that includes seeds, chaff elements, and all unidentified non-wood items, are higher than those for other material types (Figs. 4, 5, 6, 7, 8). Median values for NWDens range from 4.00 (Interior Surfaces) to 74.00 items per litre (Midden-Pits). In NWDens values are consistently high for samples from Midden-Pits, in contrast to those from other groups. Analysis of NWDens values with the Kruskal–Wallis test (Table 3) returned a p value of 0.005, indicating statistically significant context-related variation in NWDens values.

Non-wood indeterminate (cereal-type) density

Density values for the category "non-wood indeterminate (Cereal type) items", (NWIndCTDens, Figs. 4, 5, 6, 7, 8) are highly variable. Midden-Pit (50.67) and Midden contexts (19.31) have markedly higher medians values for NWIndCTDens than other context types. Analysis of NWIndCTDens values with the Kruskal–Wallis test (Table 3) produced a p value of < 0.001, indicating a strong statistical significance for context-related variation in NWIndCTDens values.

Table 3 Kruskal–Wallis test results for differences in medians for context types; significance level $p < 0.05$; bold text indicates value below significance level

	FI	ChDens	CerGrDens	WdSdDens	ChaffDens	NWDens	NWIndCerDens
p values	0.100	**< 0.001**	0.214	**0.0024**	0.084	**0.005**	**< 0.001**

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Relative density ratios

Four relative density ratios, Charcoal to Weed Seeds, Cereal Grains to Chaff, Cereal Grains to Weed Seeds, and Charcoal to "non-wood indet. Cereal-type", all standardized by volume, were also assessed with the Kruskal–Wallis test for the three recovery context types with the most samples, exterior surfaces, middens, and midden-pits. Although these could be simplified to the ratio of charcoal weight to weed seed count, for example, it was opted to retain their relative ratio structure to emphasize that what is really being compared is the *relative density* of two components in a given sample. Charcoal densities are based on the weight (in g) of > 2 mm charcoal fragments. Weed seeds represent all sizes of weed seeds above the light fraction mesh size of 0.15 mm. Of these four ratios, only Charcoal to Weed Seed Density (ChDens:WdSdDens) and Charcoal to "non-wood indet. Cereal type", (ChDens:NWIndCTDens) showed significant differences between sample medians, with a *p* values of 0.005 and 0.04. As such, these were the only relative density measure further examined with the Mann–Whitney U test.

Mann–Whitney U test results

Non-parametric analysis with the pairwise Mann–Whitney U test was conducted for selected context group pairs in order to further explore the utility of these nine measures (six density measures, *FI*, two relative density measures) for distinguishing the sub-assemblages recovered from different recovery context types. Given the low quantity of samples from Interior Surface (n = 3) and Hearth (n = 4) contexts, pairwise analysis was restricted to comparison of Midden (n = 8), Midden-Pit (n = 5), and Exterior Surface (n = 15) samples. For each pair of the selected context groups, all nine measures were analysed. The results of this analysis (Table 4) revealed several statistically significant context-related differences in composition at the $p < 0.05$ significance level for comparisons of samples from exterior surface (Ext Surf), midden, and midden pit (M-Pit) samples for the ChDens, NWDens, NWIndCerDens, *FI*, and ChDens:WdSdDens values. In contrast, no statistically significant variation was demonstrated for the other four measures (CerGrDens, WdSdDens ChaffDens, ChDens:NWIndCTDens) for any context type pair.

In order to test for the presence of type 1 errors in these results, a stepwise Bonferroni correction (Abdi 2010) was applied (Table 5). The resulting adjusted *p* values confirmed statistically significant differences among the following comparisons (Table 6): exterior surfaces vs. middens for charcoal density; exterior surfaces vs. M-Pits for NWIndCT density and charcoal density; and middens vs. M-Pits for NWIndCT density and ChDens:NWIndCTDens. Although type 1 errors cannot be ruled out for the remaining comparisons, their low probability is suggested by the similarity of the adjusted *p* values to the original *p* values.

Table 4 Mann–Whitney U test *p* values for comparisons of samples from exterior surface (n = 16 observations), midden (n = 8 observations), midden-pit (n = 5 observations), and midden and midden-pit combined (n = 13 observations) contexts

	ChDens	CerGrDens	WdSdDens	ChaffDens	NWDens	NWInd CTDens	ChDens: WdSd Dens	ChDens: NWInd CTDens	FI
Ext. surf. vs. midden	**0.001**	0.722	0.675	0.583	0.540	**0.026**	**0.009**	0.132	<u>0.075</u>
Ext. Surf. vs. M-Pit	**0.011**	0.512	0.222	0.485	**0.045**	**0.005**	<u>0.057</u>	0.304	<u>0.066</u>
Midden vs. M-Pit	0.305	0.463	0.272	0.213	<u>0.067</u>	**0.048**	<u>0.055</u>	**0.012**	0.769

Values in bold text with shading indicate statistical significance at the $p < 0.05$ level. Underlined values indicate statistical significance at the $p < 0.10$ level

Table 5 Results of stepwise Bonferroni procedure to provide adjusted *p* values to test for type 1 errors

p values in ranked order	Adjusted *p* values	Variable	Significance
0.001	0.00625	Ext. surf. vs. midden ChDens	Strong
0.005	0.007	Ext. surf. vs. M-Pit NWIndCTDens	Strong
0.009	0.0083	Ext. surf. vs. midden ChDens:WdSdDens	Possible
0.011	0.01	Ext. surf. vs. M-Pit ChDens	Possible
0.012	0.125	Midden vs. M-Pit ChDens:NWIndCTDens	Strong
0.026	0.0167	Ext. Surf. vs. Midden NWIndCTDens	None
0.045	0.025	Ext. Surf. vs. M-Pit NWDens	None
0.048	0.05	Midden vs. M-Pit NWIndCTDens	Strong

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Table 6 Summary of compositional variation among context group pairs

Context pair	ChDens	CerGrdens	WdSd dens	Chaff dens	NWDens	NWInd CTDens	FI	ChDens: WdSdDens	ChDens: NWIndCT
Ext. surf. vs. midden	**Higher midden**	–	–	–	–	**Higher midden**	Higher midden	–	**Higher midden**
Ext. surf. vs. M-Pit	**Higher/M-pit**	–	–	–	**Higher / M-Pit**	**Higher M-Pit**	Higher M-Pit	–	–
Midden vs. M-Pit	*Lower in M-Pits, but not statistically significant*	–	*More than 2× higher in M-Pits, but not statistically significant*	–	Higher (M-Pit) *Nearly 3× higher in M-Pits, but weak statistical significance (at 90% CI)*	**Higher M-Pit**	–	–	**Higher M-Pit**

Bold text indicates variation that was significant at a significance level of $p<0.005$ (Mann–Whitney U); underlined text indicates variation that was only weakly significant (significance level of $p<0.10$) (Mann–Whitney U); *italics* represent qualitative observations

Discussion

This exploratory analysis sought to determine: (1) whether the recovered charred botanical remains originate from dung, non-dung sources, or both; (2) whether or not the composition of samples from specific context types shows non-random variation that might point toward different assemblage formation processes for different context types rather than a homogenized assemblage resulting from post-depositional mixing. On the basis of the eight measures discussed above and the results of statistical analysis, significant variation in composition and preservation is apparent in the sub-assemblages from exterior surface, midden, and midden-pit contexts. The observed patterns of recovery context-related variation, shown in Table 5, may be summarized as follows:

1. Exterior surface vs. midden: Compositional patterning is greatest between the Midden and Exterior Surface groups. These groups show distinctive, highly significant differentiation in density values for charcoal ($p=0.001$), non-wood indet. (cereal-type) ($p=0.026$), and the relative density of charcoal to weed seeds ($p=0.009$) all of which are higher for the Midden group. This group also shows a weak significance ($p=0.075$) with for higher fragmentation than in the Exterior Surface group.
2. Exterior surface vs. midden-pit: As compared with exterior surface samples, those from midden-pit deposits show statistically significant compositional differences in charcoal density ($p=0.011$), non-wood density ($p=0.045$), and "non-wood indet. Cereal endosperm type" density ($p=0.005$), all of which are higher in midden-pit samples.
3. Midden vs. midden-pit: The midden and midden-pit groups also show statistically significant compositional differences from one another for three variables. These context groups are distinguished by significant differences for lower relative density values ChDens:WdSdDens and ChDens:NWIndCTDens in the midden-pit group, and higher values of NWIndCTDens in the midden-pit group. In other words, midden-pits are characterized by a statistically significant higher presence of weed seeds and "non-wood indeterminate, cereal type" fragments relative to charcoal than are middens, as well as a higher presence of "non-wood indeterminate, cereal type" fragments.

Context, taphonomy, and plant sources

The non-parametric statistical analysis applied here to investigate the relationship of sample composition and preservation with various context types reveals several statistically significant, context-related patterns within the assemblage. This patterning supports the inference that these sub-assemblages reflect variation in their sources of plant remains and the formation processes that affected their composition and degree of fragmentation. Although post-depositional processes might be argued to have biased the preservation of small seeds as compared with more robust cereal seeds and fragments, the fact that glume bases and small seed fragments are abundant in the assemblage, which was completely sorted down to the smallest size fraction, argues against this.

Exterior Surface samples are characterized by four statistically significant differences from midden and midden-pit samples: low charcoal and non-wood indet. cereal-type

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densities, and low relative densities of charcoal to weed seeds and charcoal to non-wood indet. cereal-type fragments. The low presence of non-wood indet. cereal-type fragments, particularly considered in association with the dominance of glume bases in these samples, is inconsistent with waste from daily food preparation. On the other hand, cereal grains do not reach even the 1:4 grain:chaff ratio determined experimentally for hulled barley fed to sheep and goats (Anderson and Ertug-Yaras 1998), such that the prevalence of chaff must be explained another way. While the low charcoal densities, the dominance of sheep and goat in the faunal assemblage, and the site's location (Miller 1984; Miller and Smart 1984) could also be argued to point toward dung-fuel as a source of plant remains in these samples, the relative absence of arable weeds suggests that they derive from parching. Hillman's (1981) ethnographic observations of crop processing document the use of burning and pounding to aid in the removal of the tough outer glumes of hulled cereals, such as the einkorn wheat and hulled barley represented at Fistikli, resulting in the separation of spikelet forks into individual glume bases. The degree of compositional similarity among Exterior Surface samples, the prevalence of chaff, and the paucity of field weeds shows a pattern similar to that documented by Graham and Smith (2013) for a storage deposit of cleaned emmer spikelets at Kenan Tepe that they argue represents a late stage of processing precleaned spikelets that parallels stages 6–7 as listed by Fuller et al. (2014), parching, pounding, and second winnowing/medium-coarse sieving. The most likely source of the plant remains recovered in samples from exterior surfaces is thus the routine activity of late stage cereal processing, with carbonization resulting from a combination of accidental burning during parching and the casual use of chaff as fuel, as described by van der Veen (1999). This activity seems to have been carried out regularly in the open area at the northern edge of the site (samples 10,684, 10,711, 10,784, and 10,790) and at times, also between tholoi (samples 4,298, 4,309) (Fig. 2).

In contrast to samples from exterior surfaces, those from midden-pits and middens show statistically significant associations with higher values for charcoal density and non-wood indet. cereal-type fragment density, and lower degrees of fragmentation that are not statistically significant. The higher density of cereal-type endosperm fragments that characterizes midden and midden-pit samples is more consistent with routine food preparation activities that are typically carried out near fires. Although the number of hearth and interior surface samples was too small for statistical analysis, the strikingly low counts of cereal-type endosperm fragments in these contexts as compared with middens and midden pits (Fig. 8), despite the presence of cereal grains in nearly all hearth and interior surface samples, suggests regular cleaning of these features, with redeposition of material as secondary or tertiary waste in middens and midden-pits.

Statistically significant differences between midden and midden-pit samples also emerged from this analysis, specifically, an association of midden-pits with higher values for both the density of non-wood indet. cereal-type fragments ($p=0.048$) and the relative density of charcoal to non-wood indet. cereal-type fragments ($p=0.012$) (Tables 4, 6). The higher density values for non-wood indet. cereal-type fragments in midden-pits, which are stratified beneath overlying Midden deposits, suggests that different formation processes affected these two depositional contexts. In terms of behavioural factors, midden-pits fit a pattern of dedicated use as locations for repeated disposal of food and food preparation waste. Although not statistically significant, the mean density of weed seeds in midden-pit samples is nearly twice that of midden samples, and that of non-wood density for midden-pit samples is more than three-times that of midden samples. A possible explanation for these differences is the burning of dung fuel in food preparation activities represented by the midden-pit samples, as supported by the higher weed seed and non-wood item densities, the latter of which is statistically significant ($p=0.026$). Although not statistically significant, the higher degree of fragmentation in midden-pit samples (lower *FI* values) as compared with midden samples provides tentative support for the identification of dung fuel in midden-pits, as experimental feeding has shown increased fragmentation of plant remains in ruminant dung (Valamoti and Charles 2005). The high cereal chaff densities in midden-pit samples, argued to include burned animal dung, suggests the use of cereal processing by-products as fodder. However, despite what appears to be an identifiable contribution of burned dung fuel as one source of plant remains at Fistikli, crop processing and food preparation seem to be the primary sources.

The higher *FI* values (representing lower fragmentation) for exterior surface samples as compared with midden and midden-pit samples, although not statistically significant, highlight the differential preservation of plant remains across these context types. The lower fragmentation of plant remains in exterior surface samples, despite their association with parching and pounding—activities that promote fragmentation—may reflect fewer late stage processing transformations, such as fine sieving, cooking, sweeping, and fewer effects from successive episodes of redepositions as compared with those recovered from midden and midden-pit contexts.

At Fistıklı, for the later Early Halaf, the primary source of plant material seems likely to be crop processing, specifically the dehusking of glume wheats. Carbonization of these materials would have resulted from the use of heat for parching and the use of processing by-products as both sources of casual fuel and fodder for sheep and goats, whose

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dung was later burned as fuel in certain context types. The macrobotanical assemblage attests to repeated episodes of glume wheat processing in exterior spaces adjacent to the northern edge of the site and occasionally in spaces between tholoi. While the burning of animal dung may contribute to the recovered plant materials, the primary source of plant remains for most midden and exterior surface samples is debris from crop processing and food preparation activities.

Conclusions

In summary, this analysis of contextual distribution of compositional patterns for the FHIIIa–c assemblage shows tentative evidence for dung-derived plant remains in midden-pits, but not in other depositional contexts such as middens and exterior surfaces. On the whole, the Fistikli evidence reflects a pattern noted by Charles (1998) and Fuller et al. (2014), in which dung burning adds "noise" to crop processing and food preparation waste, which are the primary contributors to the assemblage. This assemblage is most similar to those of Abu Salabikh (Charles 1998) and Kenan Tepe (Graham and Smith 2013), in that it shows evidence for both non-dung and dung-derived plant remains. While Charles (1998) and Graham and Smith (2013) apply the multivariate statistical method of correspondence analysis (CA) to tease out such patterning in their datasets, the new method developed for this study relied upon non-parametric statistical methods to examine multiple indices. In many cases, researchers have more clear evidence from which to determine the presence or absence of burned dung. For example, at Domüztepe, Whicher-Kansa et al. (2009) rely on higher wood to seed weight ratios and pollen evidence for the availability of forested areas near the site to support their argument that dung fuel was not used. Conversely, at sites such as Kenan Tepe (Graham and Smith 2013), Jeitun (Charles and Bogaard 2011), and Abu Salabikh (Charles 1998), the presence of burned dung pellets provided a clear signal that dung fuel was a source of at least some plant remains at these sites and an opportunity to test the CA models. At Fistikli however, no dung pellets were recovered and the assemblage showed circumstantial evidence for dung fuel, namely the overall low quantities of cereal grains, prevalence of chaff, high degree of fragmentation, and low charcoal densities, many of which are also consistent with certain stages of cereal processing. The new methodology developed for analysis of this assemblage reveals contextual variation in composition that reflects taphonomic processes. Although the *FI* results show that fragmentation is not a significant variable for differentiating these samples, the *FI* provides a rapid quantitative index for assessing inter-sample differences. In addition to the analysis of intra-contextual patterning, to be undertaken in a second stage of this research, it would be useful to integrate floral and faunal data on composition and preservation to assess the fit of the combined datasets with the taphonomic model proposed here.

The use of both dung and wood as fuel at Fistıklı may indicate repeated use of the site at different times of the year, perhaps for planting cereals and/or birthing and milking animals in the early spring (cf. Kansa et al. 2009), and harvesting and processing spring-sown cereals in the late summer. The abundance of neonatal and fetal sheep/goat remains reported by David Orton (unpublished report) for IIIa/IIIb midden deposits provides another line of support for this interpretation. I hope, that this discussion contributes to building on her example of attention to context, and answering the most fundamental question in palaeoethnobotany, as phrased by Miller (1989), "What mean these seeds"?

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