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The effects of cooking on avian eggshell microstructure

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ABSTRACT

Although avian eggshell is a common component of the faunal assemblages at archeological sites, attempts to identify it taxonomically and use it to construct complex economic arguments have been limited. One method of identifying avian eggshell, using a scanning electron microscope (SEM) to examine characteristic microstructures, can provide more specific taxonomic identifications. This study sought to test whether cross-culturally common egg preparation methods were likely to damage eggshell in ways that would make it difficult to identify taxonomically under a SEM. We found that most food preparation practices caused minimal or no damage. Only cooking eggs in hot coals caused significant damage to eggshell microstructures, making it impossible to identify these eggshells taxonomically. With the exception of fire-cooked eggs, the lack of damage to eggshell microstructures meant that SEM analysis was sufficient to identify cooked eggshells taxonomically but insufficient to differentiate most cooking techniques.

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1. Introduction

Avian eggshell is often recovered from archeological contexts when excavated sediments are wet-sieved through a fine mesh. Though avian eggshell may occur naturally in archeological deposits, most archeologically recovered eggshell probably results from subsistence practices. While many projects do not attempt to assign avian eggshell fragments to taxonomic classifications, some projects use DNA analysis or examination of eggshell fragments under a scanning electron microscope (SEM) to identify avian eggshell more specifically.

Identification of avian eggshell using a SEM relies on being able to identify the particular morphology of the eggshell's mammillary cones, microscopic substructures whose formation varies by species. Successful identification requires that the eggshell be sufficiently intact to preserve undamaged mammillary cones. While potential sources of damage to mammillary cones have been identified (Beacham, 2006), the potential effect of cooking methods on mammillary cones has not been investigated. This study investigates the effects of cross-culturally common egg preparation methods on eggshell mammillary cones with the goals of understanding 1) whether and how egg preparation practices can affect mammillary cones, and 2) whether any damage to mammillary cones that occurs during egg preparation can be used to identify cooking methods.

Testing the possible effects of egg preparation methods on avian eggshell is one step in establishing criteria for identifying archeologically recovered avian eggshell to species and interpreting it in terms of subsistence practices. It is known that embryogenesis has an effect on the mammillary cone structure of avian eggshell (Beacham, 2007) and that avian eggshell is sensitive to erosional processes (Beacham, 2006). However, the possible effects of cooking practices on mammillary cone structure have not been investigated. If preparation methods do affect the microstructures of the eggshell, it is important to know the extent of these changes so that accurate species level identifications can be made. In addition, if it were possible to identify whether an egg had been cooked or, further, the type of cooking method used, this information would add a new dimension to the analysis of subsistence practices at archeological sites.

Avian eggshell is composed primarily of calcium carbonate stabilized with a small amount of protein matrix (Nys et al., 2004). As a carbonate, eggshell can be expected to react to acids and heat by releasing carbon dioxide and becoming more calcined and to react to carbon dioxide-saturated water by forming soluble calcium bicarbonate. All three of these reactions could potentially occur during preparation of eggs as food if whole eggs were baked or boiled. However, the occurrence of these reactions is dependent on both temperature and CO_2 pressure in the atmosphere. The calcination of calcium carbonate occurs only above temperatures of 550 °C at normal atmospheric pressure, suggesting that calcination of avian eggshell is unlikely to occur at most food preparation temperatures. While eggshell damage due to food preparation practices is chemically possible, the actual extent of such damage and its effect on the identification of the eggshells to species have not been investigated.

Based on the chemical composition of avian eggshell, we began this study with the hypothesis that the cooking times and temperatures

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Table 1
Common egg preparation techniques with cultural references.

Egg preparation type		Culture	Country or region	Reference
Eggshell exposed to heat	Boiled	Teda	Chad	Le Coeur and Schütze (1950)
		Lapps	Finland	Itkonen and Minn (1948)
		Badagas	India	Hockings (1980)
		Koryak	Kamchatka	Jochelson (1908)
		Paiute	California, USA	Kelly (1934)
	Baked	Selk'Nam	Argentina and Chile	Gusinde (1931)
		Paiute	California, USA	Kelly (1934)
		Araucanians	Chile and Argentina	Hilger (1957)
Eggshell not exposed to heat	Fried	Badagas	India	Hockings (1980)
	Egg cakes	Lapps	Finland	Itkonen and Minn (1948)
	"Scrambled"	Lapps	Finland	Itkonen and Minn (1948)

involved in most cross-culturally observed egg preparation practices would not significantly affect the mammillary cone structures of avian eggshell and thus not prevent confident taxonomic identification. However, some low levels of change might occur that could help archeologists identify food preparation practices. We did not attempt to address the effects of burning avian eggshell as part of disposal practices, where much higher temperatures and more extended exposure to heat might occur.

2. Theory

The use of scanning electron microscopy to identify archeological eggshells has been employed only sporadically. Tyler (1970) attempted to identify avian eggshell fragments from Salamis using methods that included the examination of the eggs' mammillary cone layer. Keepax (1981) developed methodologies for taxonomically identifying eggshell fragments by examining the physical characteristics of the egg (i.e. thickness, shape, color, etc.) as well as its microstructure. Keepax (1981) noted that the microscopic structure of eggshell would be useful in identifying archeological eggshell fragments as the typical identifying characteristics of avian eggs - egg size, shape and color - would not be applicable. She outlined mammillae size, number, and height, as well as pore size, number, and shape as features that might be useful in the identification of eggshell fragments to species. Few additional studies attempted to taxonomically classify avian eggshell until the publication of Siddell's (1993) guidebook. Siddell's methodology expanded on Keepax (1981) by providing SEM images of the eggshell of numerous avian species along with the typical eggshell thickness, mammillae count, pore count, and surface descriptions for each species.

Since the publication of Siddell's manual, several studies have been conducted using scanning electron microscopy to identify avian eggshell (Beacham, 2006, 2007; Boyer, 1999; Eastham and Iolo, 1997; Lamzik, 2013). Of these studies, most have focused on the use of the SEM to identify domestication (Beacham, 2006, 2007), or to conduct comparisons between the avian bone assemblage of a specific site and its eggshell assemblage (Eastham and Iolo, 1997).

Archeological eggshell undergoes a number of destructive processes, including both taphonomic and human impacts. It has been shown that acids produced by decaying plant material can destroy calcareous eggshells and bone (Carpenter, 1982). Soil studies have shown that calcareous structures are more stable in low EH (reduction potential, or the tendency to acquire electrons), high pH soils with high levels of calcium carbonate (Retallack, 1984). In a study of both naturally eroded and experimentally treated eggshell, Clayburn et al. (2004) found that eggshell is expected to experience a greater chance of preservation in environments that are drier and alkaline. Though the mammillary structure was still evident in the naturally weathered eggshell, the detail in fresh eggshell was obliterated. In contrast, there was a deepening of craters in mammillae and dissolution of the margins of the mammillae in the experimentally treated eggshell. In addition, the dissolution of calcium carbonate from eggshell fragments occurred more rapidly the lower the pH and as temperature was increased in both the neutral and acidic solutions, there were increased losses in eggshell surface and thickness (Clayburn et al., 2004).

While the taphonomic damages to avian eggshell have been studied (Carpenter, 1982; Clayburn et al., 2004), the effect of cooking processes on eggshell structure is not yet understood. Since it is known that taphonomic processes such as acidity and weathering can impact eggshell structure, it is possible that the concentrated heat exerted during some kinds of cooking or contact with slightly acidic or carbon dioxide-saturated water during boiling might also have an effect.

3. Methods

To study the effects of preparation methods on avian eggshell, we first identified likely methods of egg preparation through ethnographic and historical research. We then prepared eggs in each of the selected methods, choosing to use chicken eggs because they and the eggs of their ancestors the guinea fowl have been used worldwide as a food source throughout prehistory and history. We examined a sample of the shell of each prepared chicken egg using a scanning electron microscope. Finally, we compared our SEM images of the prepared chicken eggshells to existing SEM images of raw chicken eggshells to assess 1) whether damage had occurred, 2) the nature of any damage, 3) whether the damage would prevent successful identification to species, and 4) whether the damage was characteristic to specific preparation methods.

Table 2
Measurements for our cooked eggshell along with Siddell's standard measurements for chicken eggshell. Standard chicken pores/mm^2 is the mean for a sample size of 20 chickens (Siddell, 1993).

	Pores/mm^2	Thickness (in mm)
Chicken (Siddell, 1993)	2.8	0.325–0.35
Raw	3	0.325
Boiled 3 min sample 1	2	0.350
Boiled 3 min sample 2	3	0.40
Boiled 12 min sample 1	3	0.325
Boiled 12 min sample 2	4	0.350
Baked 20 min sample 1	3	0.350
Baked 20 min sample 2	3	0.30
Fire cooked 10 min sample 1	1	0.325
Fire cooked 10 min sample 2	3	0.350
Fire cooked 10 min sample 3	3	0.320
Fire cooked 15 min sample 1	5	0.350
Fire cooked 15 min sample 2	3	0.350
Fire cooked 15 min sample 3	3	0.325
Fire cooked 20 min sample 1	3	0.40
Fire cooked 20 min sample 2	2	0.320
Fire cooked 20 min sample 3	3	0.325

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