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Article

Processing Technologies and Production of Food in the Jomon Period

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Processing Technologies and Production of Food in the Jomon Period

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Abstract

During the Jomon period, which lasted about 13,000 years, a variety of food processing techniques were developed. First of all, there is pottery itself, which was the most basic tool for processing food in the Jomon. Early pottery is thought to have been used for cooking and processing fish, but the number of pottery sherds excavated in the Incipient Jomon is quite limited. The number of pottery shapes increased later on, suggesting that pottery was used for various purposes and times during the Jomon period. As for food processing facilities, we can point to a series of earthen pits in the Kyushu region which are thought to have been smoking facilities, and shell mounds as food processing sites that were typically developed in eastern Japan. Each technology had its diversity depending on the period and region. Although not food itself, salt production using salt-making pottery began in the Late Jomon period. From the Late Jomon period onward, the number of water reservoirs associated with wooden structures used for processing nuts, such as horse chestnuts and walnuts, increased in eastern Japan. Although acorn and nuts had been used since the Early Jomon period, the use of lowland storage pits in the western part of Japan suggests that the use and processing of acorn and nuts changed after the Late Jomon period.

Keywords: Jomon, food processing, food processing facility, salt production, social complexity

要旨

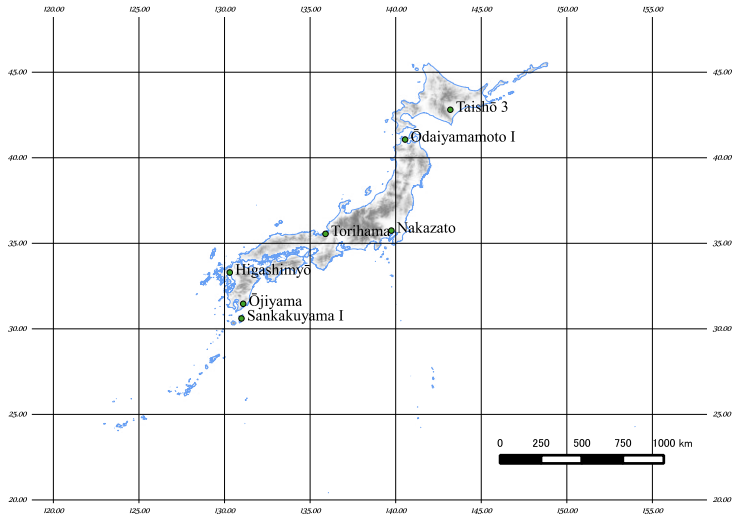
13,000 年ほど継続した縄文時代において、さまざまな食料加工技術が開発された。まずは、土器そのものであり、食料を加工する最も基本的な道具となっている。初期の土器は魚類の調理・加工に用いられたことが明らかにされているが、土器出土数はかなり限定されている。その後、土器器種が増加しており、縄文時代の各時期における土器の用途は多様であったと

考えられる。食料加工施設としては、燻製施設と考えられる九州地方の連穴土坑、東日本に顕著に発達した食料加工場としての貝塚などが挙げられる。それぞれの技術は、時期・地域によって多様性を有している。食料そのものではないが、縄文時代後期には製塩土器を用いた製塩も開始されている。縄文時代後期以降は、東日本で堅果類処理用の水場遺構・木組み遺構が増加する。堅果類は縄文時代の早い時期から利用されていたものの、西日本でも低湿地貯蔵穴が利用されるなど、縄文時代後期以降において利用・処理の方法に大幅な変化が生じたと考えられる。

キーワード：縄文、食料加工具、食料加工施設、製塩、社会的複雑化

0. Introduction

During the Jomon period, which lasted about 13,000 years, many techniques and facilities for food processing appeared. I have researched the development of food processing facilities in the Late and Final Jomon periods (Kawashima 2015b, 2016). The tradition of Jomon food processing was developed based on techniques invented in the previous stage of the Jomon. In this paper, I will review food processing techniques, including pottery, found at sites shown in Fig. 1, and will examine their social significance in relation to the social development of Jomon society.



(Global Map Japan by Geospatial Information Authority of Japan)

Fig.1: Sites mentioned in the text

1. The appearance of pottery as a food processing tool

The beginning of the Jomon period is defined as the appearance of pottery in the Japanese Archipelago, dating back to ca. 16,000 cal BP (Kobayashi 2008; Taniguchi 1999, 2011, 2017). While Jomon pottery is well-known for the artistic decoration of the Middle Jomon (Kobayashi 2004), most vessels of the earliest period were non-decorative and coarse pottery was used for cooking.

Table 1: Date of the Jomon period

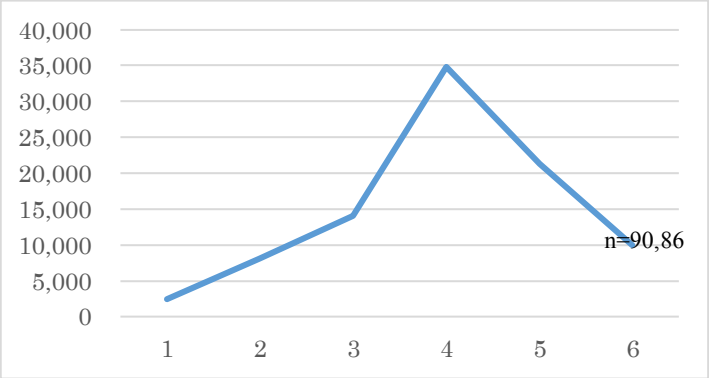
	cal BP
Incipient	16,000-11,500
Initial	11,500-7,000
Early	7,000-5,470
Middle	5,470-4,420
Late	4,420-3,220
Final	3,220-2,850/2,350

(Kobayashi 2008)

The Jomon period is divided into six sub-periods (Table 1). Of these, the Incipient Jomon (16,000-11,500 cal BP) occupies more than four thousand years, 30% of the whole Jomon period. The use of the earliest pottery is still questionable. While Kobayashi (2004) suggests that some of the early pottery resembles containers that are made of botanical materials, such as baskets, the primary function must have been a vessel for cooking. Kobayashi pointed out that the emergence of pottery played a vital role in the later development of Jomon culture, especially in the field of food processing. Therefore, the appearance of pottery in Japan is accepted as an indicator of the Jomon period.

As Taniguchi (2011) indicates, the Incipient Jomon, which occupies almost one-third of the whole Jomon period, shows significant differences from the later periods, such as the quantity of pottery and less sedentism. The number of Incipient Jomon sites is 2,432 (Japanese Paleolithic Research Association 2010), out of 90,863 for the whole Jomon period (Agency for Cultural Affairs 2017) (see Fig.2). Considering the length of the Incipient Jomon, the site density is low compared with

the later periods. Despite these differences, however, the Incipient Jomon can be recognized as the infancy in terms of food processing since basic food processing techniques had already appeared.



(Agency for Cultural Affairs 2017;
Japanese Paleolithic Research Association 2010;
Koyama 1978)

Fig.2: Approximate number of Jomon sites

The use of the earliest pottery has been mentioned in previous studies. Watanabe (1968) described that the earliest pottery served for processing nuts and acorns, which were possible staple diets in the Jomon. According to the development of shell mounds, shellfish were also presumed to have been cooked in pottery (Okamoto 1962). Further excavations revealed that pottery appeared much earlier than the formation of shell mounds. While the earliest pottery was assumed to be used for making tendon glue (Kajiwara 1998), most scholars claim it was used for cooking or food processing.

Aside from excavated charred remains, recent isotope analysis has clarified the processed material in pottery. Based on over 100 samples, Craig et al. (2013) suggest that most charred surface deposits came from aquatic products and freshwater foods. Kunikita et al. (2013) analyzed charred residues inside pottery from inland sites in northern Japan and Russian Far East. Samples from the Taishō 3 site strongly relate to marine resources and anadromous fish such as salmonids. The other sites also indicate marine processing resources, including salmonids with C_3 plants and terrestrial animals. Their study confirmed that Jomon society in northern Japan relied heavily on salmonids. Also, at the Torihama site in western Japan, where there is little contemporary salmon run, salmonids could have been

exploited during the colder climate of the Incipient Jomon (Craig et al. 2013; Lucquin et al. 2016). On the other hand, the analysis of charred surface deposits at Ōjiyama and Sankakuyama in southern Kyushu indicate that pottery was used for cooking terrestrial animal meat or C_3 plants (Kudō 2014b).

Recent lipid and stable isotope analyses suggest that most processed food would have been marine resources, including salmonids in most parts of Japan except in southern Japan where terrestrial animals or C_3 plants were processed. The analyses of charred surface deposits show tendencies of a high percentage of N, which means protein-rich food (Kudō 2014b). Kudō suggests that the earliest pottery was used for processing nuts and acorns, while he pointed out that stable isotope analysis does not reflect all the foods cooked in pottery. Also, it is notable that most pottery sherds used for lipid and isotope analyses belong to phases II and III of the three stages in the Incipient Jomon. In this sense, it should be noted that the use of the first pottery is still not clarified. However, recent analyses show that pottery was used for cooking and/or processing especially high protein foods (Craig et al. 2013; Kunikita et al. 2013; Lucquin et al. 2016; Lucquin et al. 2018).

Within the sub-periods of the Incipient Jomon, pottery was produced unevenly (Taniguchi 2011). In contrast to the rapid increase of pottery sherds in phase II, the number of pottery sherds in phase III is as small as in phase I. The same tendency was described as an S-curve dynamics (Gibbs and Jordan 2013). It seems that the number of pottery sherds was associated with climate change. This may simply indicate the possibility that Incipient Jomon sites are distributed underwater. In spite of the instability of Incipient Jomon pottery in number, the fact that excavated pottery sherds rapidly increased for the end of phase III could have been based on the long tradition of pottery used in the Incipient Jomon. Although the source of accelerating pottery production is unknown, the cooking and food processing techniques of the Incipient Jomon could have promoted the exploitation of natural food resources, which were developed in the later periods.

2. Traces of Jomon food processing facilities and tools

As noted above, pottery played an essential role in cooking and processing in the Incipient Jomon. With the progress of excavations, not only more examples of the earliest Jomon pottery, but also the emergence of food processing facilities, are becoming more evident.

2.1 Ventilated hearth

From the end of the Paleolithic to the Initial Jomon, shallow pits with an accumulation of rocks, a kind of earth oven, were constructed, which could be used for roasting/steaming food. According to ethnographic examples in Oceania, these are thought to have functioned as earth-ovens. After the Early Jomon, these outside hearths became uncommon and were generally installed in each house. Along with the rock accumulation, a type of hearth with a tunnel for smoke was constructed in the Incipient and Initial Jomon, which was called 'ventilated hearth' (Pearson 2006). While distributed widely on the Pacific side of western Japan, the center of the ventilated hearth distribution is southern Kyushu. As they were not associated with pit houses, they were thought to have been constructed outside. The ventilated hearth is supposed to have been used for smoking and cooking.

At the Ōjiyama site in southern Kyushu, charred remains were found from a ventilated hearth from the Incipient Jomon (Sasaki and Yoneda 2012). Among the charred remains, two samples were identified as chives (*Allium schoenoprasum var. foliosum*), or long-stamen chive (*Allium macrostemon*), and tree onion (*Allium fistulosum var. caespitosum*). Supporting this identification, some kinds of starch from bulbous vegetables or tubers were found by starch residue analysis (Sangawa 2012). Besides bulbs, charred remains of cotyledons of *Quercus* were found from other hearths (Obata 2012).

While the use of this type of hearth needs further investigation, according to the charred remains excavated from these hearths, plant foods were used, as well as fish and meat, as suggested by isotope analyses. Food processing techniques and possibly food storage could have been developed in the Incipient Jomon considering these facilities and pottery.

2.2 Shell mounds

Shell mounds were developed in several regions around Tokyo Bay and Sendai Bay. Most of them were formed by daily disposals due to subsistent activities, but graves and pit houses were found from layers of shells. However, some shell mound sites show aspects of food processing. At the Nakazato site, while the shell was accumulated in thick layers, up to 4.5m, artificial remains such as pottery and stone tools were scarce. There were pits associated with a wooden enclosure, paved with silts, which were thought to have been used for processing, such as steaming shellfish, and export to inland areas (Abe 2014). Layers were formed separately by large individuals of clams and oysters, which implies the seasonality of collecting clams in spring-summer and oysters in winter.

Shell mounds provide much information, but it is difficult to extract evidence of each food processing activity. Gotō (1973) suggests that the large shell mounds around Tokyo Bay in the Late Jomon were constructed to produce dried shellfish. This theory is based on the fact that salt production with pottery appeared after the construction of large shell mounds. He concluded that exported salty products increased the demand for salt in inland areas, which led to salt production in the late Late Jomon. While it should be noted that the period of the end of large shell mounds and the start of salt production are not the same, his theory proposed an important view for food processing.

2.3 Pottery for salt production

Salt production using pottery appeared in the Late Jomon, continuing until the Final Jomon, and partially until the Middle Yayoi period (Kondō 1984; Kawashima 2015a). As salt was made from seawater, salt-producing sites were distributed along the coast. Salt production has been especially studied as it represents the case of salt production by prehistoric hunter-gatherers and the exchange of relations between coastal and inland areas. Some scholars relate salt production with the great number of fishing tools, representing developed fishing groups in the Late Jomon, around Kasumigaura Lake (Suzuki 1992; Tsunematsu 1997). According to their argument, salt could have functioned as a food preservative.

However, in addition to no concrete data regarding the amount of salt produced in the Jomon, there are scarce ethnographic examples of salt usage for preserving food among hunter-gatherers and simple societies in Southeast Asia (Kawashima 2010, 2015a, 2015b). In societies in New Guinea, salt was not consumed daily but used for exchange and ritual purposes. As ritual objects increased in the Late Jomon, salt could have been used in ritual contexts.

In the Kantō region, salt pottery sherds on which secondary fire could be seen were distributed in inland sites. It is possible to assume that salt pottery could have been transported filled with salt (Kawashima 2010) or that salt was produced from salty material obtained from coastal areas. Archaeochemical analysis of inland salt pottery from the western Kantō region indicates that the pottery was locally made (Miyauchi and Kawanishi 2016). While large-scale salt-producing sites were distributed on the southern coast of Kasumigaura Lake, other production sites could have been located along Tokyo Bay (Abe 2010). In the Tōhoku region, on the other hand, the distribution of salt pottery sherds is limited to the coast. The regional difference can be seen not only in the form of salt pottery but also in the production and exchange network system.

Regarding food processing, Jomon society developed facilities and tools from the Incipient Jomon, although there were regional differences. Pottery is one of the critical tools because it enabled the cooking of staple foods in the Jomon (Kobayashi 2004).

In the following section, I will examine the development of wild plant use and its processing tools and facilities.

3. Intensive use of wild plant food resources and storage pits

The existence of agriculture and the intensive use of wild plants such as acorns and nuts would indicate storage habits and food processing. A typical storage facility is a storage pit that shows diversity in size, shape, and location. A significant difference is seen in the distribution area of storage pits.

From the Initial Jomon, wet-type storage pits appeared in western Japan which were occasionally filled with acorns and nuts at the time of discovery (Kawashima 2016). The distribution of these pits until the Middle Jomon is concentrated in Kyushu.

One recent discovery is at the Higashimyō site, where many storage pits were found with botanical remains, such as acorns and woven baskets, some 5m beneath the contemporary ground surface (Matsui and Inoue 2011:180-181). Acorns from the pits indicate the surrounding forest consisted of evergreen broadleaf trees.

There are some interpretations of the function of wet-type storage pits. As these storage pits are constructed in wetland and filled with water, they are often recognized as facilities for removing toxic ingredients from acorns. Watanabe (1969) suggests that leaching acorns was not the primary function, as the most common acorn was red bark oak (*Quercus gilva*) which does not contain toxic ingredients. Mizunoe (1999) describes that the regional tendency of acorn species can be observed by identifying acorns excavated from storage pits. In Kyushu, red bark oak is the most common species found in storage pits. In such areas the leaching function of wet-type storage pits could have had less importance. Some scholars insist that acorns were stored in the case of famine as the pits were sometimes found filled with acorns (Imamura 1988). While this might have been the case, in spite of an increasing number of excavated pits, the number of such pits filled with acorns is still small (0.83%) (Yagiura 2004). Also, as pits were not entirely under ground-water level, which would result in germination, Watanabe (1969) asserts that storage in wet-type pits was unlikely to have been used long-term.

Although it is difficult to determine the function of each wet-type storage pit, whether for short or long term, they were used as storage pits. Multiple storage pits were constructed at some sites, which indicates a repeated occupation for an extended period rather than the use of all the storage pits simultaneously (Yamamoto 1999). Jomon societies in western Japan are regarded as small and relatively migratory groups (Yano 2016). As the wet-type pits were used for storage, basically, the same group repeatedly visited the storage area. In contrast to eastern Japan, the number of Late Jomon sites in western Japan are more significant than those of the Middle Jomon. Using acorns and nuts effectively by wet-type storage pits, Late Jomon societies in western Japan could have changed their subsistence and migration strategy.

4. Cultivation of plants and use of stone adzes

In the Initial Jomon, which began almost simultaneously with the Holocene, settlements, pottery, and other artifacts increased. At this stage, the societies in the Japanese Archipelago would have possessed Jomon-like sets of artifacts (Taniguchi 2011). As noted above, various plant foods were already exploited and used at the beginning of the Jomon. Although the use of plant foods in the Jomon was underestimated, the excavation of Torihama during the 1970s and 1980s revealed that plant food was the staple diet in the Jomon, rather than animal food for example, as suggested by the remains in shell mounds. Notably, the botanical remains at Torihama, such as perilla (*Perilla Frutescens*) and gourd, suggest the existence of Jomon agriculture (Nishida 2002). The fact that wild and domesticated plants were used at the beginning of the Jomon provides a significant influence on the research of Jomon plant use.

Most Jomon agriculture would have occupied a small part of subsistence. Nevertheless, chestnut, which is thought to have been an essential food, could have been part-domesticated in the Early and Middle Jomon. Pollen analysis revealed that pollen of chestnuts appeared in a large number at the Sannaimaruyama site (Yoshikawa M. 2011). Yoshikawa first clarifies that in the surface pollen assemblages, the ratio of chestnut pollen rapidly decreases from more than 25 m. outside of the forest and suggests that pure forests of chestnut trees appeared after the middle Early Jomon around Sannaimaruyama. Such chestnut forests were identified in eastern Japan from the Early to Final Jomon. Another indicator of domesticated plants is their increased size. Yoshikawa J. (2011) reconstructs the size of Jomon chestnuts from excavated chestnuts and cotyledons. She clarifies that the size of chestnuts increased in the Middle Jomon, and that the size continued to increase further till the Final Jomon, though smaller chestnuts were also found. She estimates that the settlements maintained pure chestnut trees. Not only the chestnut fruit but also the chestnut tree provided useful material for pit houses. As Nishida (2002) suggests, maintaining valuable trees and vegetables could have led to semi-domesticated forests, and Jomon groups could have controlled the vegetation around the settlements.

However, at the end of the Middle Jomon, chestnut pollen decreased and was replaced by horse-chestnut (*Aesculus turbinate)*. The reason for the change in vegetation is generally thought to be a cold event, occurring around 4,400 cal BP (Kudō 2012). Considering the large chestnuts (Yoshikawa J. 2011) and the continuous use of chestnut trees as construction materials, chestnut trees could have existed after the Late Jomon. This issue of changing vegetation around settlements is examined below.

Using direct evidence of plant seed impression on pottery, it has been possible to examine the emergence and spread of cultivation (Nakayama 2015). Beans such as soy (*Glycine max subsp. max*) and adzuki (*Vigna angularis var. angularis*), including their wild species (*Glycine max subsp. Soja* and *Vigna angularis var. nipponensis*), were used from the Initial and possibly cultivated from the Middle Jomon (Nakayama 2015) in central Japan.

Imamura (1996) describes that the population increase in central Japan during the Middle Jomon, assumed from the number of sites and pit houses (Koyama 1978), was caused by the intensive consumption of edible tubers, such as Japanese yam, as compared with the situation in the Kantō region where acorns and nuts were the staple diet. Chipped stone adzes, which have been found in increasing numbers for that period, could have been used to harvest the yam.

Although the population increase in central Japan is supported by a recent study (Crema et al. 2016), this trend would need further investigation because the ratio of dependence on agriculture must first be examined. Although many chipped stone adzes produced in central Japan during the Middle Jomon have been regarded as a tool for harvesting Japanese yam (Imamura 1996; Hudson et al. 2008), these adzes may also have been used for cultivation.

5. Increasing food processing after the Late Jomon

Water resources were necessary for site formation during the Jomon. Water reservoirs were found from the Earliest Jomon, but increased rapidly after the Late Jomon, especially in eastern Japan (Habu 2004; Kawashima 2015b, 2016). Water reservoirs constructed after the Late Jomon have wooden structures, which in many cases were associated with the accumulation of horse chestnuts. This kind of

combination was rare before the Late Jomon. In Japan, a large body of ethnographic data of leaching horse chestnuts and acorns suggests possible Jomon techniques for consumption, providing a staple diet (Hosoya 2011). The Jomon wooden water reservoir has similar characteristics to ethnographically recorded wooden structures, *tochidana*, which were used for leaching horse chestnuts (Kawashima 2009). Topography could cause a structural difference. Jomon wooden water reservoirs in the Kanto Plain were located in a small valley with a slight angle incline. At the same time, most leaching facilities from ethnographic examples were constructed in mountainous regions with steep slopes where abundant water was readily available by using a trough. Notably, Jomon society in the Kanto Plain needed abundant clear water for the water reservoir. Such water might have been used for drinking water and processing products like fibers. However, while such activity existed in the previous periods, no wooden water reservoirs were constructed until the Late Jomon. In this sense, the existence of horse chestnuts in a reservoir implies the possibility of food processing, such as leaching horse chestnuts and acorns.

In addition, the need for intensive food processing could explain the change in pottery, for example, the emergence and increase of coarse pottery in the Late Jomon. Coarse pottery, which has less decoration, was larger and occasionally found in a pile at some large sites (Abe 2000). Abundant coarse pottery may have been used for processing acorn by boiling to remove toxic ingredients.

Social change in the Late Jomon can be seen in the settlements (Kawashima 2015b). The Middle Jomon is well known for large settlements with concentric building arrangements, this tendency ends in the late Middle Jomon, followed by a period of small settlements. In the Late Jomon, the number of settlements decreased, but most of the large settlements, at which wooden water reservoirs were constructed, were used till the Final Jomon (Kawashima 2005). Another essential feature of the Late and Final Jomon is the increase of ritual objects, such as figurines and stone rods produced in particular sites. The distribution of ritual objects was not even among the settlements but concentrated in some large long-term settlements (ibid.).

Along with increased ritual objects, as seen in the emergence of salt production, craft production would have developed in this period (Kawashima 2010, 2012). Although salt may not be included in crafts, considering the production process and the use of salt in simple societies, salt production can be discussed in the context of

craft production studies. As craft specialization is regarded as an indicator of social complexity (Costin 2005), the emergence of complex societies, to some extent, could be expected in this period (Kawashima 2015b).

On the other hand, in western Japan of the Late Jomon, as seen above, wet-type storage pits rapidly increased, and the number per site is greater than before. While the size of groups in western Japan is thought to have been smaller and more mobile than in eastern Japan in general (Yano 2016), multiple uses of the same site over a longer period occurred after the Late Jomon. In some areas, such as Kumamoto, figurines were made in large numbers. In western Japan, though regionally different, in the latter half of the Late Jomon the ratio of pottery with simple lines or no decoration became higher. These changes appeared in the same period as in eastern Japan, while the extent of the changes seems much smaller. It is difficult to determine whether these social changes in western and eastern Japan were directly linked to each other. However, it is notable that a large part of Japan shared such changes in the same period which could have been based on the development of food processing technologies.

6. Conclusion

As seen in the Incipient Jomon, techniques of processing foods were already established, which became the basis of both wild and cultivated plant use developed in each area in the later periods. While it is difficult to suppose that they were a regional tradition through the Jomon period, food processing techniques were shared in the Japanese archipelago through intra- and inter-regional networks. Therefore, some critical social changes coincided in various regions.

It is noteworthy that the period of increased wooden water reservoirs was almost simultaneous with that of increased wet-type storage pits, while there is a significant difference between eastern and western Jomon societies, especially in the density of sites (Crema et al. 2016). I have noted that the Late Jomon was a turning point toward more complex societies, which can be seen in the development of craft production, such as stone rods, clay and stone figurines, pottery salt production, and more visible traces of feasting associated with more sedentary settlements than those in the Middle Jomon (Kawashima 2012, 2015b). The intensive use of horse chestnuts in the Late Jomon period associated with

extensive food processing facilities seems contradictory to the situation of population decrease from the Middle Jomon in eastern Japan. A large amount of processed food could have been consumed by a large population or on special occasions such as feasts, and food processing facilities could have been needed to prepare a significant amount of food at once. In the Late and Final settlements, the evidence of food consumption can be seen more clearly than in the Middle Jomon, such as traces of fire, fired clay, and fragmented bones. The most different aspect of settlements between the Middle and the Late Jomon is the accumulation of soil, recognized as mounds, around the settlements which were established in the Kanto Plain. Even Middle Jomon settlements which contain many pit houses, have no such mounds. Thus, the development of food processing facilities was strongly connected to social change, as seen in the emergence of a more complex society, especially in the Late Jomon period.

* When studying at Tsukuba University, I participated in the IFERI program and was able to experience running a student conference and having discussions with students from different fields. I also had the opportunity to be involved in the international students' education in the TRANS program at Tsukuba. It was a very stimulating experience to interact with researchers from different humanities fields. As a result of these experiences, I actively participated in overseas conferences in my post-graduate research and organized sessions at some of them. Currently, I am participating in a research project on disaster prevention from a historical point of view, with researchers from geotechnology and geology. As the IFERI and TRANS program project manager, Dr. Aoki always encouraged us and promoted our research. I wish you nothing but the best in the next stage of your life.

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