【Original Article】

Data Intensive Study of Accessibility of Edible Species and Healthcare Across the Globe

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【ABSTRACT】

Variety of accessibility to edible species in different regions has climatic and historical roots. In the present study, we try to systematically analyze 28,064 records of relationships between 11,752 edible species and 228 geographic zones by hierarchical clustering. The 228 geographic regions were classified into 11 super groups named as A to K, which were further divided into 39 clusters (CLs). Of them, at least one member of each of 28 CLs is associated to 20 or more edible species according to present information of KNApSACK DB (http://kanaya.naist.jp/KNApSACK_World/top.jsp). We examined those 28 CLs and found that majority of the members of each of the 27 CLs (96%) have specific type of climate. Diversity of accessibility to edible species makes it possible to separate 8 geographic regions on continental landmasses namely Mediterranean, Baltic Sea, Western Europe, Yucatan Peninsula, South America, Africa and Arabian Peninsula, Southeast Asia, and Arctic Ocean; and three archipelagos namely, Caribbean Islands, Southeast Asian

Islands and Pacific Islands. In addition, we also examined clusters based on cultural exchanges by colonization and migration and mass movement of people and material by modern transportation and trades as well as biogeographic factors. The era of big data science or data intensive science make it possible to systematically understand the content in huge data and how to acquire suitable data for specific purposes. Human healthcare should be considered on the basis of culture, climate, accessibility of edible foods and preferences, and based on molecular level information of genome and digestive systems.

【Key words】

edible species, healthcare, ecology, constitution, genome

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INTRODUCTION

In the era of big data science or data intensive science, emphasis is given on how to systematically understand the content hidden in huge data and how to acquire suitable data for specific purposes¹⁾. Human healthcare should be considered on the basis of their own culture governed by climate, geographical accessibility of edible foods and preferences, and own molecular constitution based on genome information including digestive systems. Information on diet patterns based on individual heredity can be obtained by anthropological data, the study of various aspects of humans within past and present societies, and archaeology, the study of human activity through the recovery and analysis of material and culture. Such techniques can provide information of traditional diets which leads to ideas for solving how to make an effective diet system in a particular geographic region. Rewinding the clock back to go through the traditional products and ancestral knowledge associated with national/regional cooking make it possible to expand the food base, improve nutritional conditions and food security. Those crops which are adaptable to severe environmental conditions are beneficial to family farming, especially to the indigenous peoples. Therefore, it is important to recover and promote traditionally prepared foods based on these crops, so as to incorporate them into food assistance program, and develop innovative forms of food consumption on a broader geographic area. In the present study, we focused on accessibility of edible species across the globe because their accessibility is the most important factor in the history of food acquisition and it is helpful for examining health condition in human history.

Races evolved in Africa can get a variety of natural foods including various species of animals, plants as well as fungi and bacteria associated with fermentation process. The australopithecines emerged in the Plio-Pleistocene (from about 5-12 million years ago)²⁾. The incorporation of animal tissue into the diet occurred in the late Pliocene (2,580,000 years ago). It is almost certain that ancient humans were much better scavengers than other animal hunters because they were smaller and less muscular than modern humans and they didn't have any powerful weapons³⁾. From 1.9 million to 200,000 years ago, ancient humans tripled their brain-to-body mass ratio. In terms of the encephalization quotient, a relative brain size measure that is defined as the ratio between actual

brain mass and predicted brain mass for an animal of a given size, which was estimated to be 1.23-1.92 for the predominantly vegetarian Australopithecines and 1.41 - 4.26 for *Homo* genus⁴⁾. Brain expansion needs not only energy for its growth and maintenance but also the availability of building block such as arachidonic acid (AA), docosahexaenoic acid (DHA) and many other factors referred to as brain-selective nutrients⁴⁾. Together with the brain expansion, aquatic and maritime adaptations played a significant role in the demographic and geographic expansion of anatomically modern humans after about 150,000 years ago⁵⁾.

The expensive tissue trade-off hypothesis argues persuasively that, as mostly plant-eating australopithecines evolved into frequently-meat-eating later *Homo* species via sometimes-meat-eating early *Homo* species based on an evolutionary trade off between bowel and brain, both of them being very energy-intensive organs⁶⁾. Fully modern humans, *Homo sapiens* emerged from the Africa ancestral line of all living humans between 100,000 and 60,000 years ago. Later, between 60,000 and 50,000 years ago, a small group of these fully human hunter-gatherers left Africa. Seafood had been a significant component of the Paleolithic diet and the modern human brain probably have evolved with this diet^{7,8)}.

One of the greatest achievements of human being was the domestication of plants and animals. Just as the earliest *Homo sapiens* of 90,000 to 60,000 years ago coped with different environments as they spread across Africa so did their descendants who scattered the rest of the globe after 60,000 years ago. The African emigrants encountered diverse new environments and discovered edible plants and new animal food sources. Some ten thousand years ago the process of plant and animal domestication was simultaneously underway, in several parts of the world in Africa and Europe. During most of human evolution the dietary flexibility tended to increase⁹⁾. In contrast to the Neandertals, Upper Paleolithic humans appeared to forage on broader and more geographically variable range of plants and animals.

About 11,000 years ago hunter-gatherer diet was changed to diet with agriculture and animal husbandry. Intentional fermentation of fruit, rice or honey beverages has been carried out since about 10,000 years ago which was indicated by the chemical content with ancient Neolithic vessels¹⁰⁾. When milk

of cattle began to be utilized in food and beverage by the domestication of dairy cattle between 7,500 and 9,000 years ago, lactase persistence trait was found in pastoralist population in Europe and Africa¹¹⁾. The lactase persistence trait made it possible to use milk products for foods.

Currently, the accessibility of foods for individual geographic zones is reflected by natural causes involving climate, geographical limitation, and artificial causes for example transportation including import and export among countries. The shift from a “Paleolithic” to modern diet was clearly characterized by a reduction in the protein content of the diet and a marked increase in carbohydrates. Economic activities and globalization make it possible to spread edible species across countries using modern transport systems.

Food culture arose from the human tribe settlement, whether they still live there or not, and it is shaped by several factors, which includes factors associated with natural conditions such as climate, land soil and water, human cultural factors involving religion, education, literacy communication and ethnicity, technological factors involving hunting gathering, agriculture, horticulture, aquaculture, fishing, food processing and storage, transport, cooking, and human health factors involving genetics^{12, 13)}.

Biodiversity especially diversity of edible species represents the strength of ecosystems, and is regional theme to study the nutrition and healthcare based on diet¹³⁾ and nutrition science and food policy by applying an integrative approach to understanding health-optimising diets to achieve effective, sustainable, food productions within ecological systems¹⁴⁾.

In the present study, we try to systematically classify geographical areas based on natural food accessibility regardless of places of origin of food based on hierarchical clustering. Then, we discuss inherent healthy diets of geographic regions extracted by the hierarchical clustering and characterize eight food cultures across continents are as follows, Mediterranean, Baltic Sea, Western Europe, Yucatan Peninsula, South America, Africa and Arabian Peninsula, Southeast Asia, Arctic Ocean; and food culture of three archipelagos i.e. Caribbean Islands, Southeast Asian Islands, and Pacific islands. In addition, we also examine cross-cultural communications concerning food exchange between geographic regions. Furthermore, in the case of foods exportation produced in agriculture or/and fishery (<http://www.kantei.go.jp/>

http://singi/nousui/kyouka_wg/) based on food cultures, as an example, Washoku Japanese food culture, we also examine the importance of foods exportation toward foreign countries using food accessibility.

MATERIAL AND METHODS

Accessibility of edible species is defined as those being consumed as food by people of a targeted geographic zone. Wild species, cultivated species, species imported from other geographic zones are included in accessible edible species of a targeted geographic zone. In the present study, we examined the pattern of diversity of edible species across geographic zones.

We accumulated 28,064 pairs of relations between edible species and geographic zones comprising 11,752 edible species and 228 geographic zones from scientific references. Among the accumulated edible species 44% are plants, 25% are fish, 12% are insects, 10% are mushrooms, and 6% are other species associated with meat. All of the data is available in “KNApSACk from around the world DB” (http://kanaya.naist.jp/KNApSACk_World/top.jsp)¹⁵⁾.

In the present study we represent individual geographic zones as 11,752 dimensional binary vectors. Here, if i th species is present in j th target geographic zones, the j th element is set to 1; otherwise, the j th element is set to 0. A Tanimoto distance matrix for geographic zones has been applied to hierarchical clustering by Ward's method¹⁶⁾. The distance based on edible species patterns between geographic zones s and t is represented by E_d . (1).

$$r_{st} = 1 - \frac{N(s \cap t)}{N(s \cup t)} \quad (1)$$

Here $N(s \cap t)$ and $N(s \cup t)$ represent respectively the intersection set and union set of edible species of zones s and t .

RESULTS

The 11,752 species involved in the present analysis are much more than 7,000 species reported as commonly eaten¹⁷⁾ and one third of the reported edible plants¹⁸⁾. Furthermore 28,064 records of relationships between edible species and 228 geographic zones is significant information concerning utilization corresponding to individual geographic zones. Though, in the scientific references, information of edible species is very limited for several geographic zones, we

applied a hierarchical clustering method to systematize the relationships among 228 geographic zones and constructed a dendrogram (Fig. 1). We tentatively classified 228 geographic zones into 39 clusters (CL1 - 39) included in 10 super groups (A-K). Table 1 shows geographic zones classified into 39 CLs. Of them, we examined 28 CLs of which at least one geographic zone of each cluster is associated with 20 or more edible species according to KNApSack DB. In Table 1, the geographic zones associated with more than 20 species are written in black characters.

Food accessibility depends on several factors, that is, climate, agricultural development, transportation, fish cultivation, geography, and national boundaries¹³. Climate influences are fundamentally important for availability of edible species in the natural resources. German scientist Wladimir Köppen has proposed the five vegetation zones as follows: (i) equatorial, (ii) arid, (iii) warm temperature, (iv) snow and (v) polar¹⁹, which has been updated by Kottek et al. (2006).

Table 2 shows relationships between clusters (CLs) generated by the present study and the vegetation zones defined by Kottek et al.²⁰. Based on similarity of geographic zones, our clusters can be associated with 5 major vegetation zones as follows.

(c1) 11 clusters with equatorial climate; CL1-3, 6, 7-9, 14, 16, 17, 19, and 21.

(c2) 1 clusters with arid climate; CL23.

(c3) 6 clusters with warm temperature climate; CL11, 24, 26, 31, and 34.

(c4) 1 cluster with snow climate; CL30.

(c5) 1 cluster with polar climate; CL32.

Clusters associated to multiple vegetation zones are as follows.

(c6) 1 cluster with equatorial and arid climate; CL18.

(c7) 2 clusters with equatorial and warm temperature climate; CL11 and 16.

(c8) 1 cluster with warm temperature and snow climate; CL19.

Consequently, accessibility of edible species can be characterized by the climate of a region, that is, specific climate can be assigned to 26 CLs (92%) based on similar climate of the majority of the members included in clusters.

The cultures related with climates also affects to food accessibility. For example, fat source can be quite diverse, for example, fish, meat, grain involving soy beans, seeds involving sesame, cotton, red palm, coconut, avocado, and fruits involving olive, red palm¹³. The Mediterranean diet is a collection of similar eating habits traditionally followed by countries bordering the Mediterranean Sea²¹.

So we examined whether or not geographic zones assigned to identical clusters are spatially closed to each other.

By taking the relation among geographic zones of individual CLs in Fig. 1 into consideration, 22 CLs can be characterized by specific geographic locations on earth as indicated by maps of the countries in Fig 2. In the present study, we tentatively examined two types of levels for the clusters, comprehensive level corresponding to super groups A to H and precise level corresponding to clusters CL1 to CL39. Below we briefly discuss the clusters in the context of geographic locations.

(g1) Geographic zones in Caribbean Islands are clusterized in CL1-3 and those three are the most separated by the other geographic zones (Super group A in Fig. 1).

(g2) Geographic zones in Mediterranean are clusterized in CL4 and 5 and those two CLs are closely related (B).

(g3) Geographic zones in Southeast Asian Islands are clusterized in CL6 (C).

(g4) Geographic zones in Yucatan Peninsula are clusterized in CL7. Though geographically very near to each other but in terms of accessibility of edible species Caribbean Islands (CL1-3) and Yucatan Peninsula (CL7) are distantly related indicated by the dendrogram where CL1-3 (A) and CL7 (D) are highly separated.

(g5) Geographic zones in South America (CL8-10) are assigned to 3 CLs and those three CLs are closely related (D).

(g6) Geographic zones in Africa are clusterized into CL14, CL16, and CL19. CL14 (E) is separated from CL16 and CL19 (F).

(g7) Two clusters (CL17 and CL27) related with Indian subcontinent are distantly related with each other in terms of food. The former is assigned to F, whereas, the latter is assigned to G.

(g8) Geographic zones in Arabian Peninsula and East Africa are clusterized in CL18 (F).

(g9) Geographic zones in the Pacific islands are clusterized in CL21 (F).

(g10) Geographic zones in Western Europe are clusterized in CL24 (G).

(g11) Geographic zones in Arctic Ocean are clusterized in CL32 (G).

(g12) Geographic zones related with Scandinavia and Baltic Sea are clusterized in CL26, CL30, and CL34. The former two geographic zones (CL26 and CL30) belong to G, whereas CL34 is separated from those two (belong to H).

Fig. 1 Dendrogram of 228 geographic zones.

The 228 geographic zones are classified into 39 clusters (CL1-39) and 11 comprehensive groups (clade A-K). Members of individual clusters are listed in Table 1.

Table 1 Classification of geographic zones based on clustering.

CL	NZ	NS	Geographic Zone
1	4	176	Dominican Republic, Jamaica, Republic of Trinidad and Tobago, Bolivarian Republic of Venezuela
2	5	93	Aruba, Republic of Cuba, Puerto Rico, Curacao, United States Virgin Islands
3	11	118	Antigua and Barbuda, Barbados, Cayman Islands, Commonwealth of Dominica, Saint Christopher and Nevis, Saint Lucia, Montserrat, Saint Barthélemy, Commonwealth of The Bahamas, Republic of Haiti, Saint Vincent and the Grenadines
4	5	169	Amb Republic of Egypt, Hellenic Republic, Kingdom of Morocco, Republic of Turkey, State of Israel
5	14	104	Republic of Albania, Bosnia and Herzegovina, Republic of Cyprus, People's Democratic Republic of Algeria, Republic of Croatia, Republic of Lebanon, Principality of Monaco, Republic of Malta, Republic of Montenegro, Republic of Tunisia, Libyan Arab Jamahiriya, The West Bank and Gaza Strip, Syrian Arab Republic, Republic of Slovenia
6	6	369	Republic of Indonesia, Brunei Darussalam, Malaysia, Republic of the Philippines, Republic of Singapore, The Democratic Republic of Timor-Leste
7	5	80	Republic of Guatemala, Republic of Honduras, Republic of Nicaragua, Republic of Panama, Republic of El Salvador
8	6	51	Republic of Bolivia, French Guiana, Republic of Paraguay, Republic of Suriname, Oriental Republic of Uruguay, Co-operative Republic of Guyana
9	2	28	Guadeloupe, Martinique
10	3	185	Republic of Colombia, Republic of Ecuador, Republic of Peru
11	5	86	Republic of Korea, Bermuda, Kingdom of the Netherlands, Taiwan, Republic of Costa Rica
12	3	7	(<i>Republic of Niger</i>), (<i>Burkina Faso</i>), (<i>Republic of Mali</i>)
13	2	2	(<i>Western Sahara</i>), (<i>Republic of Guinea-Bissau</i>)
14	5	14	(<i>Republic of Liberia</i>), (<i>Republic of Cote d'Ivoire</i>), Republic of Ghana, (<i>Republic of Sierra Leone</i>), (<i>Republic of Togo</i>)
15	4	6	(<i>Republic of The Gambia</i>), (<i>Republic of Equatorial Guinea</i>), (<i>Gabonese Republic</i>), (<i>Republic of Guinea</i>)
16	9	72	Republic of Burundi, Democratic Republic of Congo, Republic of Mozambique, Republic of Uganda, Republic of Benin, Republic of Malawi, United Republic of Tanzania, Republic of Zambia, Republic of Zimbabwe
17	5	81	(<i>Kingdom of Cambodia</i>), People's Republic of Bangladesh, Democratic Socialist Republic of Sri Lanka, Union of Myanmar, Socialist Republic of Viet Nam
18	12	30	Islamic Republic of Iran, Kingdom of Saudi Arabia, Islamic Republic of Afghanistan, Federal Democratic Republic of Ethiopia, (<i>Republic of Iraq</i>), Republic of Mauritius, (<i>New Caledonia</i>), Republic of Madagascar, (<i>Republic of Seychelles</i>), (<i>Antarctica</i>), (<i>British Indian Ocean Territory</i>)
19	7	29	Republic of Angola, (<i>The Republic of the Sudan</i>), (<i>Belize</i>), Central African Republic, Republic of Cameroon, Republic of Senegal, Republic of Congo
20	5	10	(<i>American Samoa</i>), (<i>Guam</i>), (<i>Kingdom of Tonga</i>), (<i>Republic of Vanuatu</i>), (<i>Independent State of Samoa</i>)
21	7	64	Cook Islands, Republic of the Marshall Islands, French Polynesia, Tokelau, Republic of the Fiji Islands, Federated States of Micronesia, The Island of Hawaii
22	2	3	(<i>Republic of Kiribati</i>), (<i>Republic of Nauru</i>)
23	22	11	Republic of Botswana, (<i>Republic of Djibouti</i>), (<i>Papal Islands</i>), (<i>Republic of Liechtenstein</i>), (<i>Republic of Maldives</i>), (<i>Northern Mariana Islands</i>), (<i>Niue</i>), (<i>Pitcairn</i>), Republic of Palau, (<i>Rodrigues Island</i>), (<i>South Georgia and the South Sandwich Islands</i>), (<i>St. Helena ex dep.</i>), (<i>Solomon Islands</i>), (<i>Republic of Somalia</i>), (<i>Republic of San Marino</i>), (<i>Somali Democratic Republic</i>), (<i>Tuvalu</i>), (<i>Wallis and Futuna</i>), (<i>Grenada</i>), (<i>Mongol Uls</i>), (<i>Democratic Republic of Sao Tome and Principe</i>)
24	5	435	Spain, Republic of Italy, Federal Republic of Germany, French Republic, United Kingdom of Great Britain and Northern Ireland
25	6	32	Portuguese Republic, Republic of Armenia, Swiss Confederation, Hashemite Kingdom of Jordan, Kyrgyz Republic, Republic of Poland
26	5	53	Ireland, Kingdom of Denmark, Kingdom of Norway, Kingdom of Sweden, Kingdom of Belgium
27	4	319	Kingdom of Bhutan, State of Nepal, Islamic Republic of Pakistan, Republic of India
28	11	287	Federal Republic of Nigeria, Federative Republic of Brazil, Republic of Kenya, Lao People's Democratic Republic, Papua New Guinea, The Kingdom of Thailand, Republic of South Africa, Argentine Republic, Commonwealth of Australia, Republic of Chile, New Zealand
29	4	214	Republic of Bulgaria, Hong Kong Special Administrative Region, Russian Federation, Ukraine
30	3	149	Republic of Belarus, Czech Republic, Republic of Estonia
31	4	1924	People's Republic of China, Japan, The United Mexican States, United States of America
32	4	145	Republic of Iceland, Greenland, State of Alaska, Canada
33	3	9	(<i>Republic of Austria</i>), (<i>Slovak Republic</i>), (<i>Grand Duchy of Luxembourg</i>)
34	5	16	(<i>Republic of Finland</i>), Republic of Hungary, (<i>Republic of Lithuania</i>), (<i>Republic of Latvia</i>), (<i>Romania</i>)
35	3	10	(<i>Former Yugoslav Republic of Macedonia</i>), (<i>Republic of Kosovo</i>), (<i>Republic of Serbia</i>)
36	8	8	(<i>Republic of Azerbaijan</i>), (<i>Georgia</i>), (<i>Republic of Kazakhstan</i>), (<i>Republic of Moldova</i>), (<i>Republic of Tajikistan</i>), (<i>Turkmenistan</i>), (<i>Republic of Uzbekistan</i>)
37	5	2	(<i>Union of Comoros</i>), (<i>Republic of Cape Verde</i>), (<i>Kingdom of Lesotho</i>), (<i>State of Qatar</i>), (<i>Republic of Rwanda</i>)
38	4	2	(<i>State of Eritrea</i>), (<i>Islamic Republic of Mauritania</i>), (<i>Kingdom of Swaziland</i>), (<i>Republic of Chad</i>)
39	7	5	(<i>United Arab Emirates</i>), (<i>Kingdom of Bahrain</i>), (<i>State of Kuwait</i>), (<i>Sultanate of Oman</i>), (<i>Democratic People's Republic of Korea</i>), (<i>Réunion</i>), (<i>Republic of Yemen</i>)

Geographic groups are assigned by CL1-39. NZ, NS represent the number of geographic zones and that of edible species included in individual CLs. Parentheses represent the geographic zones with the number of edible species less than 20.

Table 2 Climate of geographic groups in geographic zones with edible species larger than 20.

CL	Equatorial				Arid				Warm temperature								Snow								Polar		Majority of climate classification	Location in Earth
	At	Am	As	Aw	BSk	BSh	BWk	BWh	Csa	Csb	Cwa	Cwb	Cfa	Cfb	Cfc	Dsa	Dsb	Dwa	Dwb	Dwc	Dfa	Dfb	Dfc	Dfd	ET	EF		
1	1	3		3																								Caribbean islands
2	1	1		3																								Caribbean islands
3	2	7		3																								Caribbean islands
4				1			1	2	4	2												1						Mediterranean
5							2	1	4	8	1		4															Mediterranean
6	5	1		1																								South East Asian island
7	1	4		4																								Yucatan Peninsula
8	3	1		4							2	2																South America
9	2																											South America
10	3	2		3									2												1			South America
11	1	1									1		3	1				1										
14																												West Africa
16	1	3		5							5																	Middle & East Africa
17		4		1	4						1																	South East Asia
18	1		3		2	3	1	2	2	2				2														East Africa, the Arabian Peninsula
19			4	2		2		2	2																			Middle Africa
21	6	1																										Pacific Islands
23					1		2	1																				
24									2	2			1	5	1													Western Europe
25							1	1	1	1			1			1	1				1	1	1	1	2			
26														4											1			Scandinavian countries
27	1			1				2			1	3																The Indian sub-continent
28	3	5	2	7		2	3	3	2		2	1	5	2														
29											1		2							1	1	1	2	1				
30													1									2						Baltic Sea
31	1				1	1	2	1	1	1	1		3						1	1	1							
32															1										3	1		Arctic Ocean
34									2								1											Baltic Sea & Scandinavian

Majorities of climates are discriminated by colors.

Fig. 2 Geographic relationship among 18 clusters which could be explained in 11 geographic zones.

Of 28 CLs in Table 2, 22 CLs can be characterized by specific geographic locations. Of remaining 6 CLs, 5 CLs (CL11, 23, 28, 29, 31) can be characterized by climate. Therefore, 27 CLs can be explained simply by either climate or by geographic location.

Human consumes a strikingly diverse species in diet. The intensification and extensification of global trade have greatly increased the diversity of accessible edible species for human. Rapid economic and income growth, urbanization, and globalization

lead to a dramatic shift of Asian diets²²⁾. Several clusters comprise of geographic zones which are distantly separated with each other, and those can be explained by the similar accessibility to edible species by globalization. For example, the geographic zones included in CL28 are distributed across equatorial and/or warm temperature climate. All geographic zones of this cluster except Thailand have been through colonization, which is also reflected by the pattern of the accessibility of edible species.

DISCUSSION

1 Clusters explained by food cultures in geographic properties

Based on accessibility of edible species, the clusters can be classified into eight geographic regions, on continental landmasses, these are Mediterranean, Baltic Sea, Western Europe, Yucatan Peninsula, South America, Africa and Arabian Peninsula, Southeast Asia, and Arctic Ocean corresponding to c1-c8, respectively, in Fig. 2; and three archipelagos which are Caribbean Islands, Southeast Asian Islands, and Pacific islands corresponding to a1-a3, respectively. Thus, total 11 geographic regions have been extracted from specificity of edible species.

Various types of healthy diets have been proposed in these decades, for example low-carbohydrate diet which restricts intake of total carbohydrate below some particular threshold and an operational definition is derived from Dietary Reference Intakes of the Institute of Medicine, which recommend to set total mean daily carbohydrate intake as below 45% of total calories²³⁾. The carbohydrate-restricted diets are utilized in diabetes management including insulin therapy and weight control^{24,25)}. Low-carbohydrate eating is associated with quite limited population group and cultural experience, for example, Inuit diet²⁶⁾. Taking intake of meat and dairy into consideration, the Atkins Diet was proposed as newer versions of low-carbohydrate which increases saturated fat intake²⁷⁾. A low-carbohydrate dietary pattern based on high-protein plant rather than animal food called eco-Atkins diet was also proposed based on the Atkins Diet²⁸⁾.

Low-fat diets include vegetarian and traditional Asian diets. Vegetarian diets are mostly plant-based system, they may include dairy and eggs typically and other animal products such as fish and other seafood selectively²⁹⁾. Because we need to take diets in two major viewpoints, that is, ecology and healthcare into consideration, we examine relationships between human health and individual local diets developed in different geographic regions.

2 Clusters related with biogeography on the continent

2.1 Africa and Arabian Peninsula

The earliest evidence for the possible use of aquatic resources by hominids come from East African Rift Valley localities where the remains of a variety of aquatic or amphibious fauna have been found with stone tools of about 2.5 to 17 million years ago⁵⁾.

Geographic zones of east Africa and the Arabian

Peninsula (Fig. 2), mostly belong to super group F (CL16, 18, 19). Those zones are associated with the area where the genus *Homo* evolved. The fossil evidence indicates that *Homo* arose in the vicinity of the East African Rift Valley lakes⁴⁾. The diverse alkaline-fresh-water fish species in the lakes provided a source of both proteins and polyunsaturated fatty acids (PUFAs). Lipids of the freshwater fish have rich contents of DHA and AA in comparison of the other foods⁴⁾.

Remains of 55 food plant taxa were excavated in Geshen Benet Ya'aqov (GBY) located in the northern Jordan Valley on the shoreline of ancient lake Hula which are estimated to be of the Lower-Middle Pleistocene period, some 780,000 years ago. GBY was Mediterranean climate 780,000 years ago because most tree species found at GBY were also found in Mediterranean³⁰⁾. The food plant remains were part of a much more diverse diet including food plant species, fish³¹⁾, amphibians, reptiles, birds, mammals such as fallow deer³²⁾, elephants³³⁾, and various aquatic and terrestrial invertebrates³⁰⁾.

Eaton and Konner indicated the possibility that the range of optimal nutrient combinations to support good health are present in the foods in Paleolithic period (2.5 million to 10,000 years ago)³⁴⁾. In addition, seaweeds containing iodine was a significant component of the Paleolithic diet because iodine deficiency results in impaired neurologic development⁷⁾. Furthermore, potential benefits of seaweeds on obesity has been reviewed in Lange et al³⁵⁾.

Modern analogues for pre-agricultural diets based on tropical marine and lacustrine resource evolved in those geographic regions. Cat fish comprised over 90% of the fish fauna recovered from over forty Late Pleistocene Nile River and East African Rift Valley lakes which had a relatively high AA and DHA⁴⁾.

Together with Paleolithic diet, procurement of animal resources was also included in the diet in Ethiopia before 2 million years ago and in Kenya before 1.95 million years ago³⁶⁾.

Traditionally, the various cuisines of Africa use a combination of locally available fruits, cereal grains and vegetables, as well as milk and meat products, and do not usually get food imported. In some parts of the continent, the traditional diet features a lot of milk, curd and whey products.

Lactose intolerance is due to the lack of enzyme lactase which hydrolyzes lactose into glucose and galactose. Several symptoms by milk maldigestion

including abdominal pain, bloating, diarrhea, gas, and nausea are caused by accumulation of un-metabolized lactose in human body. Lactose tolerance is advantageous in the environments and cultures where humans have access to domesticated dairy animals. Multiple lines of evidence from human genetics, cattle genetics, and archaeological records suggest that populations in Middle East and North Africa domesticated cattle between 7,500 and 9,000 years ago, and these animals were later brought into Europe. In that cow-friendly environment, if people can obtain nutrient by drinking milk directly (instead of having to process it into lower-lactose cheese), it is advantageous for nutrition and for a source of water during droughts. The lactose persistence mutation arose randomly, and once it arose, it had a distinct advantage in these populations and led to the lactose tolerance mutation. Recent evidence suggests that cattle may have been domesticated independently in several places including Africa, Europe and so on. In the case of Africa, lactose persistence became an advantageous trait after populations began herding cattle (estimated as 3,000-7,000 years ago)³⁷⁾ and the stage was set for the spread of a lactose tolerance mutation so called “the genetic roots of Africans' lactose tolerance” which has also occurred in Europe around the same age³⁸⁾. Thus, the convergent evolution of African and European populations in relation to cattle domestication reveals that shared aspects of human culture across different ethnic groups affect our evolution in similar ways.

Lactate persistence trait is dominant in milk-dependent nomads of the Afro-Arabian desert zones as well as in Northwestern European, for example, Swedish, Danes, Irish, British, Finland, Germans, Czechs, Swiss, Spanish, and Estonia. In Afro-Arabian desert zone, the pastoralists tend to have higher frequencies of lactase persistence than the neighboring non-pastoralists in the same countries^{11, 39)}.

Depending on the region, there are also sometimes quite significant differences in the eating and drinking habits and proclivities throughout the continent's vast populations: Central Africa, East Africa, the Horn of Africa, North Africa, Southern Africa and West Africa each have their own distinctive dishes, preparation techniques, and consumption mores. Based on accessibility of edible species, we have four clusters (CL14, CL16, CL18, CL19) and three of them (CL16, CL18, CL19) belong to super group F, and the other CL14 belongs to super group E. There is a trend that the former corresponds to the area related with

pastoralists, and the latter to the non-pastoralists. Ghana consists of Yoruba peoples belongs to CL14. Nowadays, the Yoruba don't herd cattle, and don't have any mutations for lactose persistence³⁷⁾.

The Maasai are seminomadic pastoralists distributed in East Africa, northern Tanzania and southern Kenya that they migrate within semi-arid lowlands and more humid uplands to obtain water and pasture and a large majority of the population has obtained their livelihood through husbandry of cattle, goat and sheep. It is well known that in their traditional culture, Maasai people exclusively consume meat, milk, and blood, that is, cholesterol rich diet, and the occurrences of heart disease and atherosclerosis are very low. Their adaptation for a high cholesterol and high-fat diet is associated with that lactose and lipid metabolism⁴⁰⁾.

Meat, milk, blood, and soups were the basic traditional foods of the Maasai, while herbs were either added to them or consumed directly. By the survey of 120 households, total 35 species are listed, 11 species for grains, legumes and nuts, 6 species for roots and leafy vegetables, 11 species for wild fruits, 15 species for herbs, 17 species for animal products, 2 species for fish and 2 species for sugar and cooking oil. Several herbs play nutritional roles to provide a variety of important micronutrients involving vitamin C, non-heme iron, selenium, zinc, calcium⁴¹⁾.

The low levels of coronary risk factors and low mortality from cardiovascular causes can also be interpreted by the very high levels of energy expenditure of the Maasai, that is, the Maasai people generally walk at least 19 km more per day. Habitual physical activity and cardio-respiratory fitness contribute regulation of metabolism and major determinants of modern lifestyle diseases such as Type 2 diabetes and cardiovascular disease⁴²⁾ which can be supported by the evidence that the physical activity levels of rural East Africa including Maasai are 15-20% higher than recent estimates from rural West Africa⁴³⁾. Therefore physical activity as well as diet patterns should be taken into consideration for healthcare of individual geographic areas⁴⁴⁾.

Preservation and maintenance of the Maasai traditional indigenous food-based knowledge can be carried out through integration between the existing health and nutrition interventions with traditional food promotion as well as continuous education of young members of the community about their traditional food systems and their cultural contexts⁴¹⁾.

Indigenous Arabs are direct descendants of humans who migrated out of Africa, before others continued

on to colonize Europe and Asia⁴⁵⁾. This is consistent with our results where gulf and east African regions are clusterized in the same super group F (Fig. 2).

The Arab cuisine encompasses a wide variety of local cuisines covering the Arab world from Mesopotamia to North-Africa. Originally, the people of the Arabian Peninsula relied heavily on a diet of dates, wheat, barley, rice, meat and yoghurt without butter fat called 'leben'. Flat bread 'couscous' and rice are staples and olives, as well as dates, figs, and pomegranates are widely used⁴⁶⁾. In gulf region, a radical change in dietary patterns from a traditional diet to a less healthy industrialized diet leads to a worsening prevalence of non-communicable chronic diseases⁴⁷⁾. Therefore, the selection of a healthy diet based on the food dome, dietary guidelines for Arab countries and the undertaking of physical activity are essential in the prevention of these diseases⁴⁸⁾.

Wheat (*Triticum dicoccoides*)⁴⁹⁾ and barley (*Hordeum vulgare*)⁵⁰⁾ were the first crops to be domesticated in Fertile Crescent between 12,000 and 10,000 years ago. Wheat was used for making bread in Egypt by 5,000 BC as main staple in the diet and its cultivation had spread to Europe by 4,000 BC. As farming started in the Middle East around 11,000 years ago, cattle herders learned how to reduce lactose in dairy products to tolerable levels by fermenting milk to make cheese or yogurt⁵¹⁾.

Grains such as wheat and corn except wheat germ, generally tend to be low in lysine which is one of the essential amino acids, namely, human metabolic system cannot biosynthesize lysine and must rely on adequate dietary intake⁵²⁾ of other sources, mainly animal proteins, such as meats, poultry and, milk and its fermented products are rich source of lysine^{53,54)}. Development of both agriculture and animal husbandry led to provide important role for sustaining human health in view of nutrition including fermented foods as well as foods originated in plants and animals.

2.2 Western Europe

After the development of agriculture and animal husbandry, human dietary choices would have been extended. In addition, milk was also utilized for nutrition and the lactose persistence mutation spread through ancient European populations as well as Africa³⁸⁾. Many thousands of years later, we see the indirect (but delicious) effects of this mutation's success in European cuisines: oozing French cheeses, Swiss milk chocolate, and creamy Italian gelatos. Food found in Western diets

generally unavailable to pre-agricultural period are milk, cheese butter, grains, high-fructose corn syrup, salad with cooking oil, shortening, margarine and so on⁵⁵⁾. This transition occurred too recently on an evolutionary time scale for human genome to adjust and lead to so-called diseases of civilization in Western population⁵⁵⁾.

Populations of European origin have lower rates of glucose intolerance and diabetes than do other populations (Amerindians, Polynesians, Chinese, Australian Aboriginals, Africans and South Asians) and might reflect, at least partly, a regional divergence in population genetics due to the different timings and types of agrarian transitions during much of the past 11,000 years¹⁴⁾.

The Western dietary pattern is characterized by a high consumption of red meat, refined grains, processed meat, high-fat dairy products, desserts, high-sugar drinks, and eggs. In the 14th century, average per capita meat intakes in traditional agricultural societies were 5-10 kg a year. In most subsistence peasant societies, meat was eaten no more frequently than once a week and relatively larger amounts were consumed, as roasts and stews, only during festive occasions. Growing populations needed conversion of pastures into arable land, which lead to reduce average per capita meat supply in many countries of early modern Europe⁵⁶⁾. By gradual intensification of farming, animal foods provided generally less than 15 percent of all dietary protein, and saturated animal fats supplied around 10 percent of all food energy for preindustrial populations at the 18 century. Currently, meat consumptions for French and Britain reached around 120 kg/capita and 80 kg/capita, respectively⁵⁶⁾. Based on accessibility of edible species, 5 geographic zones corresponding to Western and Southern Europe are clustered in CL24 (Super group G, Fig. 2). A high intake of red meat including meat products increases the risk of nutrition-related diseases such as cardiovascular diseases, type 2 diabetes and several cancers, whereas high levels of dietary fiber-rich cereal products, vegetables and fruit can decrease the risk of those diseases^{57,58)}.

Compared to omnivores, vegetarians generally have lower blood pressure and body weight closer to desired levels⁵⁹⁾. There are five type of plant-based vegetarian diets which permitted fish, eggs, milk and dairy products for pesco vegetarians; eggs, milk and dairy products for ovo-lacto vegetarians, milk and dairy products for Lacto vegetarians, eggs for ovo vegetarians, and non-permitted other than plants

for vegans²⁹⁾. A meta-analysis indicated trend that persons with a vegetarian diet exhibited a lower risk of metabolic and cardiovascular diseases than persons not on a vegetarian diet and the risk of ischaemic heart disease and cancer were lower⁶⁰⁾ though the lower risk of disease is presumably not only due to nutritional differences⁶¹⁾. There were no differences with respect to mortality of pesco, ovo-lacto vegetarians and vegans with people who took a high vegetable mixed diet, containing low levels of meat and meat product⁶²⁾. Therefore, it can be assumed that a plant-based diet with or without low levels of meat is associated to reduced risk of nutrition-related diseases in comparison with the currently conventional German diet²⁹⁾.

The animal-based foods contribute to the supply of the nutrients including proteins, essential amino acids, eicosapentaenoic acid (EPA), DHA, vitamin D, riboflavin, vitamin B12, calcium, iron, iodine, zinc, and selenium. As vegetarian diets including only plants contribute to the supply of those nutrients insufficiently, especially, a vegan diet increases the risk of vitamin B12 deficiency. Therefore, the German Nutrition society (DGE) recommended that vegetarians and vegan should replace meat, fish, milk and eggs with legumes, such as peas, beans, chick peas and lentils, or with soya products and other protein sources²⁹⁾.

Consequently, the risk is determined by food composition, particularly the balance between animal and plant-based foods. Common fermented foods in Western diet such as yogurt, cheese, sauerkraut, sourdough bread, beer, and wine have health-modulating potential. Lactate biosynthesized by *Lactobacillus* and *Streptococcus* reduces pro-inflammatory cytokine secretion of TLR-activated, bone-marrow-derived macrophage, dendritic cells in a dose-dependent manner⁶³⁾ and alters redox status by reducing the reactive oxygen species burden in intestinal enterocytes⁶⁴⁾. B vitamins including folate, riboflavin, and B12 are biosynthesized from various non-vitamin precursors by dairy food^{65,66)}. So fermented foods may contribute to brain health via direct and indirect pathways because fermentation may amplify the specific nutrient or phytonutrient content of foods, the ultimate value of which is associated with mental health⁶⁷⁾.

2.3 Mediterranean

Mediterranean diet is originated from a collection of eating habits traditionally followed by people in the different countries surrounding the Mediterranean

Sea²¹⁾, which has fertile soils and abundant sunshine, both of which are key factors in agriculture and is the best known and best researched example⁶⁸⁾. Based on accessibility of edible species, 18 geographic zones corresponding to Mediterranean are clustered in CL4 and 5. Both clusters are closely related with each other because they belong to the same Super group B (Fig. 2).

Archaeologist have found evidence for the production of wine in Iraq and Egypt at 8,000 and 3,000 years ago, respectively⁶⁹⁾ and in that time, these fermentation technologies expanded from Mesopotamia through the world, for example, the cultivation of grape vine and the production of wine has spread all over the Mediterranean Sea towards Greece (4,000 years ago) and Italy (3,000 years ago)⁷⁰⁾. The particular focus was on mimicking the traditional diet emphasized on olive oil, vegetable, fruits, nuts and seeds, beans and legumes, selective dairy intake, wine and whole grains, often seafood including fish, quite limited consumption of meat and moderate wine intake^{71,72)}. Meta-analysis of the Mediterranean diet on health confirmed a significant protection against major chronic diseases such as neoplastic diseases, cardiovascular diseases, neurodegenerative diseases including Parkinson's disease and Alzheimer's disease^{21,73)}.

2.4 Baltic Sea

Locally oriented and culturally appropriate dietary patterns in areas other than around the Mediterranean should be explored because several of the ingredients of the Mediterranean diet do not grow well in many areas, therefore require greenhouse or long-distance transportation. Thus New Nordic Diet or Baltic Sea Diet has been proposed by geographic zones surrounded by Baltic Sea^{74,75)}. The four criteria for choose ingredients are constructed for a more health-enhancing and environmentally friendly ways. (1) Ability to produce locally over large areas within the Nordic countries without usage of external energy: (2) A traditional as a food source within the Nordic countries: (3) Possessing a better potential for health-enhancing effects in similar Mediterranean foods: and (4) Ability to be eaten as foods not as dietary supplements. Then, the following ingredients are selected; native berries, cabbage, native fish and other seafood, wild and pasture-fed land-based animals, and rapeseed oil, and grains (oat, barley, rye). Healthy Nordic Food Index (HNFI) was also developed for evaluation of the health effects of adhering to a Nordic Diet⁷⁶⁾ and the negative relation between HNFI score and the incidence of colorectal

cancer was demonstrated⁷⁷⁾. Based on the accessibility of edible species, 8 geographic zones surrounding the Baltic Sea are clustered in Super group G (CL26 and CL30), whereas 5 geographic zones are clustered in Super group H (CL34). Depending on accessibility of edible species, healthcare diets should be separately designed for Super groups G and H. Healthy new Nordic Diet⁷⁸⁾ includes fruits (e.g. apples and pears), berries (e.g., lingonberries and blue-berry jam), vegetables, legumes, low-fat dairy products, fatty fish (e. g. salmon, herring and mackerel), and oats, barley, soy protein, almonds and phyllium seeds⁷⁹⁾.

2.5 Southest Asia

According to the accessibility of edible species, Southeast Asian countries (CL17) are assigned to Super group F whereas the countries of the Indian sub-continent (CL27) are assigned to Super group G. Though these countries are geographically nearer, they are different in terms of pattern of edible foods and this difference can be attributed to geographical separation by Ganges Valley. Thus, food culture is significantly different between the west and east sides of the Ganges Valley. In these both geographic regions and other parts of Asia, people eat rice as common staple. The archaeological evidence suggested that more than 10,000 years ago, ancient people began to gather and consume *Oryza rufipogon*, a wild grass species grew in the swamps and marshes throughout tropical and subtropical Asia. A process of continuous selection for desirable feature made it possible to transform wild rice into *O. sativa*^{80,81)}, whereas genetic support that two genomes of 110 LTR retrotransposons in the genomes of two rice varieties, Japonica rice (*O. japonica*) and Indica rice (*O. indica*) diverged from one another at least 200,000 years ago and Indica rice and Japonica rice arose from two independent domestication events in Asia⁸²⁾ and *O. indica* and *O. japonica* genomes diverged at 440,000 years ago based on the analysis of 9,383 substitutions in 972 kb of common sites⁸³⁾. The rice domestications occurred in different parts of the southeast world such as on the west side of the Ganges Valley (*O. aus*), southern Asia on the east side of the Ganges Valley (*O. indica*), and east Asia (*O. japonica*)⁸⁴⁾. Thus, the history of domestication of rice species is reflected in the classification obtained in the present work based on accessibility to edible species.

People in India utilize fermented foods based on butter and several spice and grains produced by several crops, for example, pulses urad, mung, masoor,

rice, back gram, Bengal gram, finger millet, horse gram and so on. During fermentation, microorganisms can produce important nutrients such as Vitamin B12, beta-galactosidase enzyme, and lysine from leucine. People cook tropical fruits (banana, jackfruit, monkey jack, Bael fruit, mango, Jamun fruit, Papaya, bitter gourd, and so on) and green leafy vegetable (spinach, radish, tomato, ginger, and so on). Milk by cow, buffalo, and goat, and fermented milk including clarified butter (called ghee in India), curd, paneer (india cheese), cheese and buttermilk indian yoghurt (dahi) were consumed at 2,800 years ago⁸⁵⁾. Turmeric is known as the “golden spice” as well as the “spice of life”, and has strong associates with the sociocultural life of the people of the Indian subcontinent documented by at least 6,000 years ago. It is native to South Asia, India and Indonesia, and is predominantly grown in South India and widely used in traditional Indian medicine as well as a dietary spice⁸⁶⁾. Thus, plant foods are popular rather than animal foods and probiotic processed foods are also traditionally invented in India. Yoga asanas and breathing excercises are important parts of health and spiritual practices in Indo-Tibetan traditions⁸⁸⁾.

Cuisines of East Asia, the east sides of the Ganges Valley, fundamentally consists of rice, fish and vegetables. Animal proteins obtained from aquatic organisms including fish, shells, prawns, shrimps, squids and so on. Fermented foods using aquatic organisms are consumed daily. Rice is a source of vegetable proteins, amino acids and energy. Various kinds of fish sauces, traditional food supplements in the diet, are used as a staple ingredient in various cuisines in Indo-Chinese peninsula including Myanmar, Cambodia, Philippines, Thailand, Lao and Vietnam. Ruddle and Ishige have indicated that the-Thai-Lao adopted initially the use of fermented fish from the earlier inhabitants after entering the Indo-Chinese peninsula⁴³⁾. Shellfish, Fish, edible algae and fermented fish are sources of vitamin B12⁸⁹⁾.

2.6 Arctic Ocean

Geographic regions surrounding Arctic Ocean are clusterized into CL32 (Super group G) which is closely related with CL30 (Baltic Sea). Humans first moved to the North American Arctic (northern Alaska, Canada, and Greenland) from the Bering Strait region beginning around 6,000 years ago⁹⁰⁾. Though only a period of 6,000 years, individual inuits adapted cold environment and a limited accessibility of edible species.

The traditional Inuit diet has little in the way of

plant food, no agricultural or dairy products, and was unusually low in carbohydrates. Most part of nutrition is obtained from fish and animals. Vitamins A and D are consumed by cold-water fishes and sea mammals as well as from the animals' livers. Vitamin C is consumed by freezing meat and fish, for example, raw caribou liver, seal brain, raw kelp, whale skin and muktuk⁹¹⁾.

Inuits in Greenland and Alaska have adapted limited availability of crops and vegetable in cold environment by fatty acid metabolism, and low-carbohydrate diet. Greenlandic Inuit and lower incidence and morbidity associated with coronary heart disease⁹²⁾. Inuits have probably adapted to the cold Arctic climate and invented their traditional diet, which has a high content of omega-3 PUFAs derived from seafood⁹³⁾ and a content of omega-6 PUFAs that is lower than in Danish⁷⁵⁾. The strongest signal of selection is located within a region on chromosome 11 encompassed five genes (TMEM258, MYRF, FADS1, FADS2, and FADS3) examined in 191 individuals of the indigenous Greenlandic Inuit⁹⁴⁾. FADS1, FADS2, and FADS3 have fatty acid desaturases, that is, delta-5 desaturase (FADS1), delta-6 desaturases (FADS2), and unknown function gene (FADS3). FADS1 and FADS2 correspond to the rate-limiting steps in the conversion of omega-6 and omega-3 unsaturated fatty acids to the longer, respectively. EPA and DHA classified into omega-3 unsaturated fatty acids, whereas arachidonic acid classified into omega 6 unsaturated fatty acids. Polymorphisms in or near TBX15 on chromosome 1 are detected in Greenlandic Inuit. TBX15 plays a role in the differentiation of brown subcutaneous adipocyte and brite inguinal adipocyte⁹⁵⁾. On stimulation by exposure to cold, brite adipocyte can differentiate into cells capable of expressing UCP1 (uncoupling protein 1), which produces heat by lipid oxidation. Thus, TBX15 is a candidate of adaptation to cold.

Analysis of skeletal muscle biopsies in the genotyped 2,733 participants in the Inuit Health in Transition cohort Lower of Greenland revealed mRNA and protein levels on the long isoform of TBC1D4, and lower muscle protein levels of the glucose transporter GLUT4 with increasing number of alleles with mutation at the 684th amino acid from arginine to termination codon. Here TBC1D4 affects glucose uptake and occurs at high frequency only among the Inuit⁹⁶⁾. TBC1D4 is associated with nonsense variation with type 2 diabetes, and mutation of GLUT4 elevates circulating glucose and insulin levels after an oral glucose load⁹⁶⁾.

Polymorphisms in FADS1 and FADS2 are associated

with increased level of plasma and erythrocyte delta-5 desaturases in Alaskan Inuit⁹⁴⁾ as well as with levels of PUFA in blood and breast milk^{97,98)}. In addition fermented seal fat is the most commonly consumed traditional foods and offers the nutrients produced by fermented process⁹⁹⁾. Thus, in the case of Inuit, balanced nutrients are obtained from animal raw and fermented foods and the metabolic pathways are strengthened in fatty acids in genome levels for adaptation of limited plant foods.

2.7 Yucatan Peninsula

Geographic zones in South America are clusterized in CLs7-10 in the same Super group D. Thus, the accessibility of edible species tends to be conserved in South America. Of them, CL7 is separated from other clusters CL8-10 in Fig. 1. Modern native Americans are descendant from Siberian ancestors who moved into eastern Beringia between 26,000 and 18,000 years ago, spreading southward into the Americas after 17,000 years ago, then inhabited the Yucatan Peninsula at 12,000-13,000 years ago¹⁰⁰⁾. Yucatan Peninsula belongs to the physical landscape of the Maya area. Maize was an important crop along with squash and beans and domesticated in the Central Balsas Valley by 8,700 years ago^{101,102)}.

The first developments in agriculture and the earliest villages were established in Maya Lowlands by the Archaic period (~5,000 years ago). Their diets consisted of ramon nuts (*Brosimum alicastrum*), root crops (*Manihot esculenta*), maize, fish, seafood, a wide variety of terrestrial animals including deer, peccary, and tapir. Of them, maize was a major food source at all time in Maya civilization from pre-Classic to Historic times¹⁰³⁾ and includes a variety of nutrients, that is, starch, proteins, oils, a number of important B vitamins, folic acid, vitamin C, provitamin A (i.e., precursor to vitamin A), phosphorus, magnesium, manganese, zinc, copper, iron and selenium, and has small amounts of potassium, calcium, and dietary fiber. However, maize contents low level in lysine and tryptophan which are among 9 essential amino acids¹⁰⁴⁾. Cacao (*Theobroma cacao*) also played a significant role in Classic period Maya civilization¹⁰⁵⁾ and it contains all amino acids including tryptophan which is contained in non-protein forms. Here tryptophan is the second most deficient amino acid after lysine¹⁰⁶⁾. In fermented process of cacao, tryptophan is transformed into tryptamine and 5-hydroxytryptamin (serotonin)^{106,107)}, which can affect central nervous system. Modern Mayan diet has those

traditional foods. Based on traditional Maya diet, new Mayan cuisine has been established in today's modern food practices and developed a great diversity of foods such as chocolate, avocado/guacamole, tortillas, and tamales and so on.

2.8 South America

Human populations first occupied high elevations in the Andes Mountains at least 7,000 years ago. A richness in flora and fauna of the Andes derived from the vast geographical extension and specific soil and climate conditions made it possible to produce a broad variety of traditional crops including tubers, roots, cereals, vegetables, fruits and the raising of animals such as guinea pigs and camelids^{108,109}.

Positive selection in the region of 82.0-82.3 Mb in chromosome 10 is observed for Andean natives and, Aymara and Quechua who live in the high altitude (> 2,500 meter above sea level) and FAM213A in the region is associated with accelerated growth in lung volume and chest dimensions¹¹⁰. It might be a developmental compensatory response to high-altitude hypoxia¹¹¹. This indicates that adaptation to high altitude has been carried out in genetic level, though the region would not relate with the Andes diet.

Potatoes are an important staple for the Peruvians who consume 253 g/adult equivalent/day on average and provide ideal sources of energy, proteins, fats, vitamins except B12, minerals, and fiber¹¹². Vitamin B12 can be complemented by Cheese which is a key ingredient in Andean dishes¹¹³, and other animal source foods (meat, eggs, milk)¹¹⁴.

3 Clusters related with biogeography of the islands

In the accessibility patterns of edible plants, three groups of geographic zones are dominated by archipelagoes as follows: CL1-3 (Super group A) associated with Caribbean Islands, CL6 (Super group F) with Southeast Asian Islands, and CL21 (Super group F) with Pacific Islands. Asian Islands and Pacific Islands are more similar in terms of edible patterns compared to Caribbean Islands. In general, islands have a less diverse range of species than the mainland because of the difficulties that animals often faced in getting to the islands⁶⁹ which leads to a limited types of animals for food. Otherwise people can easily access to fish and seafood and their diets tend to incline towards seafood and plants including crops.

3.1 Caribbean Islands

CLs 1 to 3 correspond Caribbean islands, and those are isolated from the other clusters as well as two clusters associated with Southeast Asian Islands and Pacific Islands. This means that accessibility patterns of edible species of the Caribbean Islands are very different from other geographic regions.

The first wave of human colonization in the Caribbean islands was started around 6,000 years ago¹¹⁵. The food remains from Banwari Trace in southwestern Trinidad suggest the change of economic shift from hunting/fishing/collecting to fishing/hunting/collecting¹¹⁶. This change of the order of economic shift depended on the cultural patterns for people who had lived along the river systems of South America utilizing marine resources¹¹⁷.

Caribbean diet tends to be rich in meat and high carbohydrate foods such as yams, sweet potatoes, plantain, cassava, beans etc. One of the main problems is the amount of meats in diet, that is the amount is traditionally generous. The use of fatty meat and products build up cholesterol leading to heart problems¹¹⁸.

The main fisheries resources in Jamaica are coral reef fishes, (i. e. snappers, groupers, jacks, goatfishes, parrotfishes, grunts, triggerfishes, doctorfishes, squirrelfishes, angelfishes), spiny lobsters, conch, small coastal pelagic finfish and large offshore pelagic finfish¹¹⁹. Cuisine called Cou-cou is part of the national dish in Barbados made from ground corn (cornmeal) and boiled okras, cooked into a firm paste which is usually served with steamed fish and frizzled salt fish¹²⁰.

Caribbean people can easily access to seafood but the problem is the cost of food. Henry et al examined the relationship between cost and healthy rank for commonly consumed foods in Jamaica¹²¹. They classified foods into 6 categories, staples, vegetables, food from animals, legumes and nuts, fats and oils, and fruits. This study reveals that healthy options for 'food from animals' are substantially more expensive in Jamaica.

In Mesoamerican diet including Caribbean diets, fermented, mildly alcoholic, and nutritious beverages are part of the daily, for example, pozol, made out of maize, pulque, produced from the agave cactus plant and so on. Pozol is traditional fermented maize dough prepared by Indians and mestizos in southeastern Mexico. It includes microbial assemblage in a spontaneous lactic acid fermented food. Lactic acid bacteria accounted for 90 to 97% of the total active microflora¹²². Thus, Caribbean diet consists animal, plant and their fermented foods.

3.2 Southeast Asian Islands

According to accessibility of edible species Southeast Asian Islands are clusterized in CL6 (Super group C), which are different from those of continental Southeast Asia (CL6 in Super group C; CL17 in Super group F; CL27 in Super group G). *Homo* genus was present on the East Indonesia island of Flores by at least 880,000 years ago which is a possible evidence for *Homo erectus* crossing of initial water gap from Sunda to Flores¹²³⁾.

People in the Philippines, Malaysia, and Indonesia use coconut oil or butter as their source of fat and rice as staple, other carbohydrate-rich foods included cassava, corn, sago or noodles, although they were sometimes considered as snacks. The main protein source in Indonesia is fish.

Nutrients are sufficiently obtained from plants based on tropical fruits and vegetables because Indonesia and the Philippines are amongst the world's megabiodiversity countries¹²⁴⁾.

Fermented soybean food, Tempe is very popular and a staple food in Indonesia and Malaysia and originated hundreds of years ago in central and east Java Island¹²⁵⁾. The earliest version of tempe is 'Sambal Lethok', a dish made of overripe tempe, recorded in a 17th-century Centhini (old Javanese) inscription. The first occurrence of the word for soybean in ancient Javanese documented in the Sri Tanjung from the 12th-13th century¹²⁶⁾. Tempe is a highly nutritious, easily digestible and tasty product. Soybeans, and thus soybean tempe, contain all essential amino acids, low in saturated fats and free of cholesterol¹²⁷⁾.

3.3 Pacific islands

From the earliest stratum of shell middens, fishing and seafaring at several sites in Melanesia islands were spread by 35,000 years ago^{5,128)}. The Pacific Islander's original diet consisted of taro, breadfruit, yams, coconut, arrowroot, bananas, and seafood. Maize, cassava, sweet potatoes, chicken and pork were introduced by Spanish and rice by Japanese. In the 1940' after World War II, there are virtually no obesity, hypertension or diabetes among population. The Pacific Island's diet transitioned to predominantly rice and imported food when the United States occupied Micronesia beginning in the 1960's and 1970's. Current Micronesia's diet mainly consisting of rice, wheat flour, sugar, refined foods, and fatty meats lead to high obesity and diabetes rates¹²⁹⁾. Thus many factors involved in history, landscape, climate change

urbanization, and population growth have led to current food situation and health status in the Pacific islands.

Promoting traditional foods and the cultivation of these foods are expected to cause the change in their diet and physical activity patterns because a study of the Aborigines people, an indigenous group in Australia indicate that a group of Aborigines people who had changed to a modern diet and lifestyle were convinced to switch back to their traditional diet, leading to significant improvement in health¹³⁰⁾.

Their traditional diet is based around whole fruits, vegetables and seafood and provides well balanced one. A wide variety of seafoods and fishes are the sources of proteins. The most traditional cooking style is "umu", an underground cooking style where wrapped food was cooked on heated rocks¹³¹⁾. Breadfruit has been a staple food and traditional crop in the Pacific for more than 3,000 years¹³²⁾. Fruit part of breadfruit are generally cooked by roasting whole in hot coals, boiling or baking. Since breadfruit is a seasonal crop Pacific islanders have developed techniques to preserve breadfruit based on fermentation process, called ma (Marquesas), mahi (Cook & Society Islands) masi (Samoa & Tonga), madrai (Fiji), namandi (Vanuatu), mahr (Pohnpei), furo (Kosrae), and bwiru (Marshall Islands)¹³³⁾. Some evidence indicate a potential that a traditional diet based on breadfruit and other Pacific staples of prevent onset of type II diabetes^{132, 134, 135)}.

4 Clusters based on cross-cultural communication

Exchanging process of people and materials such as colonization and transportation are also reflected in accessibility of edible species. CL28 consists of colonized territories where Chile and Argentina were colonized by Spain; Kenya, Australia, South Africa, New Zealand and Nigeria were colonized by Great Britain; and Lao, New Guinea and Brazil were colonized by French, Netherlands and Portuguesa, respectively. Those colonization process led to similar accessibility of diversity of edible species linked to Europe. Thailand has a potential to incorporate cuisines from surrounded geographic regions and thus got included in this cluster. Thai traditional medicine is derived from Ayurvedic and Chinese sources¹³⁶⁾. Thai also imported from India some ideas about the cooling and warming properties of food and how food affects individuals at certain stages of their life cycle in seasons¹³⁶⁾. The cooling and warming food system was also developed as body balance based on culinary

art in Chinese traditional medicines, for example, the concept of “Yin and Yang”, that is, the idea that there are two opposing phases in every aspect of life and condition of health is considered to be the principle to keep the balance of dietary. Here there are different types of the opposing sides, food to cool and warm body, male and female, dark and light, soft and hard and so on¹³⁷⁾.

CL31 consists of People's Republic of China, Japan, the United Mexican States, the United States of America. Major climate classification of China corresponds to warm temperature climate, fully humid & hot summer (Cfa) but China has an incredibly vast mix of geography and climate. These geographic zone have a geographic common future, that is, “westward intensification.” Various ocean currents are flowing throughout the world, and they have a great influence on the ecosystem. Kuroshio Current is flowing in the waters around Japan. It is a north-flowing ocean current on the west side of the Pacific Ocean. Typically, in the west side of the ocean, the ocean current becomes stronger because it is pressed against the continent in a lagging rotation of the earth. This phenomenon called westward intensification, Kuroshio current in the Pacific Ocean, and Gulf stream in the Atlantic Ocean. It is known that biodiversity in the sea is enhanced by westward intensification¹³⁸⁾, therefore a wide variety of marine products can be obtained in these geographic zone.

In the southeast, there are lush tropical rainforests, in the southwest the snow-capped Himalayas, the north is near-frozen tundra, and dry deserts spread central and western China. Those led to very diverged edible species and very diversity of cuisine. There are actually eight different cooking styles corresponding to provinces, Anhui, Guangdong (Cantonese), Fujian, Hunan, Jiangsu, Shandong, Szechuan (or Sichuan) and Zhejiang. Those are reflected by a rich tradition drawn from history and culture in their cuisines⁷¹⁾. Modern Japanese cuisine is the outcome of a tripod of Chinese, Western, and Japanese cuisine constructed in the early 20th century¹³⁹⁾.

After World War II, Japanese began absorbing some Western ways of life and continue to consume some of the high-calorie, high-fat foods featured in the American diet, including bread, ice cream, doughnuts, hamburgers, French fries and pizza. The difference between Japan and the US is size of cuisines, that is, “Japanese-sized, not American-sized,” For instance, a regular size pizza in Japan has a diameter of about

nine inches whereas, in the States, a twelve inch pizza is a medium pizza. That means that a regular pizza in Japan is about 56% of the size of an American medium pizza. This situation can be interpreted by a Japanese proverb, “Hara hachibu”, which means “stop eating when they are 80% full.” Mexico, about a third of the size of the US, but it has highly diverged geographies, and deep history of food. Thus geographic zones having access to highly diverged species are clusterized in CL31. In Chinese medicine, disease has historically been associated with body constitution which is thought to be the result of both inherent and acquired factors and Constitution in Chinese Medicine Questionnaire (CCMQ) has been developed by Qi et al¹⁴⁰⁾ which has also been utilized in Japan¹⁴¹⁾. Japanese and Chinese versions (CCMQ-J and CCMQ) consist of 60 items with 9 sub-scales labeled as “gentleness,” “qi deficiency,” “yang deficiency,” “yin deficiency,” “phlegm wetness,” “wet heat,” “blood stasis,” “qi depression,” and “special diathesis.” The eight subscales except “gentleness” correspond to Mibyou types; its original meanings are overcoming disease's future aggravation as well as prophylactic measures to maintain healthy state¹⁴²⁾. Suzuki et al have proposed the recovery system based on physical exercise¹⁴³⁾ and/or utilization of foods based on nutrition science¹⁴³⁻¹⁵³⁾.

Ministry of Agriculture, Forestry and Fisheries in Japan examined the possibility of export for foods produced in agriculture or/and fishery areas in Japan to foreign countries (http://www.kantei.go.jp/jp/singi/nousui/kyouka_wg/). Rice is the most important crop because it is a staple food in Washoku, Japanese food culture registered with the agreement of the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) as an Intangible Cultural heritage of Humanity (Registration)¹⁵⁴⁾. Its annual yield reached 8,044,000 tonnes ranked as the 14th highest in the world according to the survey in 2016 by Food and Agriculture Organization of the United Nations (FAO) - FAOSTAT Production (<http://www.fao.org/faostat/en/#data/QC>). On the other hand, it is worth noting that dietary based on rice is associated with the genotypes. Most Japanese individuals have more than two diploid copies of the salivary amylase genes (AMY1)^{155, 156)}. The mean diploid copy number of AMY1 within 1KJPN data set comprised by the whole genome sequences of 1,070 healthy Japanese individuals was 8.27¹⁵⁶⁾, which is significantly higher than the number reported in populations with low consumption of starch (5.44)¹⁵⁵⁾. Copy number is positively correlated with

salivary amylase concentrations^{155, 157)} and reflects digestion of starchy foods such as rice and potatoes¹⁵⁸⁾. These results suggest starch digestion and glucose adsorption are very diverged among individual humans. In the field of development of functional foods based on Washoku toward foreign countries, we should consider human genetic systems as well as food preference associated with information on accessibility of food in traditional and current states.

CONCLUSION

Diet and physical activities are the most important factors for sustainable society throughout human history. Traditional foods have been established since long time ago based on accessibility of foods in individual area by taking ecology of individual area into consideration. As it is shown in examples of diet systems, we initially need to consider food accessibilities on the basis of climate and geographic properties to construct healthy food systems. Generally, traditional foods originated from animals, plants and fermented foods are associated with the makeup of balanced diets in harmony with the original backgrounds of individual areas. In addition, to maintain good health we also need to consider cardio respiratory exercise in slow pace. Through the human history, we have developed very diverged way to sustain healthy condition in different ecosystems across the globe which should be taken into account for the development of healthcare systems around the world.

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要 旨

データサイエンスから解明される世界の食用生物の多様性とヘルスケア

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本研究は、アクセスできる天然食材による世界の地域の類似性を把握する目的で、世界中の文献を調査し、各地域の天然食材の情報を集積し、データ・サイエンスにより食材活用から世界の地域を分類した。11,752 種の食用生物と 228 地域から構成される 28,064 件の天然食材とそれを活用する地域の関係に基づいて、クラスター分析法により分割される 39 個のグループについて、天然食材の活用による地域の類似性を検討した。すべてのデータは KNApSACk データベース (http://kanaya.naist.jp/KNApSACk_World/top.jsp) より閲覧可能である。この 39 グループについてさらに包括的グループ A ~ K を定義し、地域の天然食材の多様性を解析した。大陸では地中海、バルト海、西ヨーロッパ、ユカタン半島、南アメリカ、アフリカとアラビア半島、東南アジア、北極海の 8 地域、また、諸島ではカリブ海諸島、東南アジア諸島、太平洋諸島の 3 地域にそれぞれ共通する天然食材を活用する傾向がある。このような天然食材の多様性は、地理的要因、気候要因、海流の影響、および物流により特徴づけられる。さらに、これらの天然食材による人のゲノム遺伝学への影響について考察した。データ・インテンシブ・サイエンスでは、膨大なデータの内容を体系的に理解し、特定の目的に関する情報得ることが目標である。人の健康を持続可能なエコシステムと関連付けるといふ課題の解明における本研究有効性を示した。また、日本の農林水産省が目指す、和食をもとづいた農作物の世界への輸出における本データベースの活用法を提案した。

キーワード: 天然食材, ヘルスケア, エコロジー, 体質, ゲノム