Fermentology • Book

The World's Oldest Cheese and Yoghurt

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Abstract

[Jessica \(Jessie\) Hendy](#) is a lecturer in paleoproteomics at the University of York where she studies ancient proteins associated with foods in archaeological sites. Jessie will describe her research at ancient archaeological sites in Turkey, Mongolia and elsewhere to understand, using ancient protein analyses, the beginnings of milk fermentation. She will take viewers on a journey to one of her archaeological sites, describe her approach to archaeology and consider take homes from her work with regard to what anyone can do in their kitchen with milk today. Jessie has recently made major discoveries with regard to [the history of Mongolian dairying](#) and dairy fermentation and [the oldest dairy fermentation in the world](#).

This talk was sponsored and supported by the Max Planck Institute's ERC-funded project, [Dairy_Cultures](#).

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The World's Oldest Cheese and Yoghurt | Fermentology mini-seminars

Introduction

In this talk I'm going to:

1. Give you an overview of what we know about dairying in the distant past
2. Provide a tour of ancient dairying practices from around the world
3. Discuss some of the latest findings using archaeological science to discover more about this really important and fascinating food

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[Dairying and poultry farming hold first place in Connecticut agriculture.](#)

Cows just outside of Wallingford, Connecticut. Sept., 1940. Delano, Jack, photographer. Image from Library of Congress.

Milk

Milk is a hugely important food and has really an enormous culinary history. What I find so fascinating about it is that it brings together really multiple domains of life into one food. Of course the domesticated animal that produced the milk, the bacteria and yeast used in the creation of specific dairy products, as well as, of course, the human creativity and ingenuity that went into creating a food source with such a vast culinary diversity.

[Large wooden couch with speckled cows.](#) Goddess Hathor ; headrests, vase & ivory boat. Egypt, Cairo. [Between 1934 and 1939]. Image from Library of Congress.

So why is this interesting to study from a archaeological perspective?

To answer that question, I'm going to turn a little bit into the present. The global production of milk is increasing, especially in Asia, and now exceeds 800 million tons every year. This is having consequences, not only just for the kinds of foods that people consume, but it's also impacting environments and infrastructures.

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“Food historian Anne Mendelson examines how varieties of animal milk have been processed and consumed since antiquity in her new book, *Milk: The Surprising Story of Milk through the Ages*.” From [NPR’s Special Series: Fresh Food](#).

While overall milk production and consumption is increasing, what's fascinating is that the majority of the world's population are actually lactose intolerant.¹ That means that they don't have a genetic trait that enables the digestion of that milk sugar,

lactose, into adulthood. Milk contains a sugar called lactose, and lactose contains two parts galactose and glucose.

[Structure of beta-D-Lactose](#). Image from Wikimedia.

As an infant, your gut produces an enzyme, like a kind of like a molecular machine, called lactase. This enzyme acts like a scissor and cuts this sugar in half, then meaning that it can be digested into the body. For most people, this enzyme stops being produced when you're weaned, or when you grow into adulthood. But for some populations around the world, this kind of gene switch stays on, meaning that they keep producing this enzyme and lactose can still be consumed without any negative side effects.

This genetic trait of keeping this switch on has evolved in multiple populations around the world. It's really fascinating to think about why:

- How can it be that dairy consumption is somehow so powerful that it can start to shape our own genomes?
- How long have humans been experiencing this evolution?
- How long have humans and animals been in this kind of evolutionary interplay together?

Let me give you an overview of what we know about some of the earliest dairying around the world.

Early Dairying: A History

Cattle, sheep, and goat started to become domesticated around 10,000 years ago. That means that humans started to tame and live together with animals and started to utilize what we call secondary products. Secondary products are things like milk and wool — products that don't necessarily result in the slaughtering and the killing of the animal. This domestication occurred in what is today Turkey, Syria, and Iraq.

Around 8,000 years ago, another kind of cattle appeared to be domesticated around the Indus Valley — this is called [Zebu cattle](#). Yet, the extent to which people were using the milk of these animals isn't really so well understood. Zebu cattle is still common in the Indian subcontinent and the African continent today.

The earliest evidence of horse milk has been reported from 4,500 years ago in Kazakhstan in the site of Botai.² Recent genetic evidence, taking DNA from the bones of those horses that they found at those archaeological sites, shows that these horses actually weren't the species that we see today. They're actually a species that have now gone wild: [the Przewalski's horse](#). It's really fascinating.³

Zebu in Wukro, Ethiopia, 2012, Bernard Gagnon. Image from [Wikimedia Commons](#).

Takhi – Przewalski's horses, Hustai National Park, 2013, Zazaa Mongolia. Image from [Wikimedia Commons](#).

But how does the practice of dairying and these domesticated animals then spread to different parts of the world?

Around 8,000 years ago, domesticated sheep, goat, and cattle started to appear in North Africa and then move further South. At this time, the Sahara desert was actually quite green and lush. But as climatic changes occurred, these animals moved further South.

I'm talking about these animals as if they are moving around on their own accord, but actually they were likely tied to human populations that were moving around or people were exchanging the animals or that knowledge about how to make those dairy foods.

In Europe, these domesticated animals seem to have moved with Neolithic farmers as they spread across the continent. These animals in Neolithic communities start appearing in Eastern Europe around 8,000 or 9,000 years ago and then reached Britain around 6,000 years ago.

What was going on for the East? Our picture of this is a little bit less clear. Animal remains crop up at archaeological sites, but it's a bit hard to tell whether they're wild animals or domesticated animals. Recently we have been able to find that around 5,000 years ago, people were eating dairy foods in what is now Mongolia — and I'm going to discuss how we actually did that study.

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["Originalen stammer fra et album eid av lektor og geolog Adolf Larsen Dal \(1863-1948\)." ca. 1890-1900. Finnmark. Ellisif Wessel \(1866-1949\). Image from Nasjonalbiblioteket / National Library of Norway.](#)

There's still a lot we really don't know about ancient dairy foods. For example: today [reindeer](#), [Bactrian](#), [dromedary camels](#), and [yaks](#) are used for their milk in various places around the world, but we really don't have a sense of when this started. These are really important species today for many groups around the world, but we really have no idea when those species started to be utilized.

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The Study of Ancient Dairying

How do we know what we do know about ancient dairying? How do archaeologists go about studying it?⁴

First of all, archaeologists can examine the animal bones that are found at archaeological sites that might come from animals that were used for dairying. What they can look for is the proportion of male and female and young and old animals. If a herd was used for dairying, it would be comprised of proportionately more older females and younger male animals. For example: if you were to find a lot of younger male cow skeletons and a lot of older female skeletons, that would suggest that those young male animals are being killed when they're young and the older females are being kept. The older females are being kept for producing milk for much longer.

Another way is to examine the objects that are found on archaeological sites that might be associated with food.

Commonly in archaeology, this is in the form of pottery or ceramic vessels — especially before the use of metal for cooking. This involves scraping off some of the inside surface of some of those artifacts, some of those ceramic pots, and extracting out the fats. And then, because of a particular kind of chemical signature in those fats, the chemical signature or the isotopic signature tells us whether those fats came from animal meat or animal milk. You can't necessarily tell what kinds of species are being used, but instead whether dairy products were used in that kind of pottery or cooking vessel — which can be extremely informative. This technique has been really revolutionary in changing our understanding about those really early dairying practices.

[Relief depicting cattle farming](#), ca. 2323–2150 B.C., Old Kingdom. Image from The Metropolitan Museum of Art.

Sometimes archaeologists find actual, whole, preserved foodstuffs. It's an archaeologist's dream to find something like this. But, as you might imagine, it's extremely rare. Some examples of these include Bog Butters.^[1]

[Bog butter in wooden vessel. 15th -16th century.](#) Found near Portadown, County Fermanagh, Ireland. In the Ulster Museum, Bazonka. Image from Wikimedia Commons.

Bog Butters are butter or dairy products, sometimes other kinds of animal products, that are found preserved in bogs. And this particularly occurs in Ireland. Then what researchers have been able to do is radiocarbon date these preserved butters to find out exactly when they were made. Researchers found out they go back around 3,500 years. They probably weren't put there by accident, but put there deliberately to preserve them because the bog is a very oxygen-free environment, meaning that organic remains survive very well. If environmental conditions are also dry, this can also preserve foods in their intaked form.⁵

Some examples of this are Xinjiang, China, where these incredible Bronze Age foodstuffs still survive, including these cheese curds that were found

together with a mummy and a preserved grass basket, which has a lining of milk residue. Also, recently in Egypt a preserved whole dairy product was excavated. These are really, really interesting, but very rare findings.⁶

Finding Evidence with Dairy

Recently, myself and my colleagues, we've been trying to find new ways of finding this evidence of these ancient dairy products. What kinds of species were being used by people in different places in different times? What kinds of products were people making?

It's also likely that these early farmers were lactose intolerant — and that means that they would have had to process the dairy foods in such a way that those sugars were broken down. Can we look at archaeological evidence to try and get at that picture as well?

I'm going to focus now on two discoveries that we've made:[\[2\]](#)

1. We've been able to extract food proteins, including milk, from pottery vessels used by some of those early farmers in their food and culinary practices.
2. We've been able to find milk proteins surviving in dental tartar or so-called dental calculus. This is plaque that becomes hard and then sits on your teeth.

I'm going to introduce you now to the site of [Çatalhöyük](#).⁷ This is a pretty famous archaeological site that's found in south-central Turkey and dates to the Neolithic periods, a time when people had moved away from hunting and gathering to a more settled community based on foods from domesticated plants and animals.⁸

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Images of Çatalhöyük from [flickr](#).

Çatalhöyük became famous for a number of reasons. Firstly, the architecture is just incredible. It's formed as a kind of proto-city by these really dense network of houses. What's cool about it is that people would have maybe walked around on top of the houses and descended into the house from above, which I think is just really neat, but also kind of a fire hazard.

What's also interesting is that people seem to have incorporated animal iconography and cattle remains into the architecture of the houses. This suggests the animals, that cattle, may have played some kind of important symbolic role in this culture.

Pottery + Dairy

[Excavation in Trench 5, West Mound.](#)
[Photographed by Peter Biehl.](#) Çatalhöyük
(2012). Image from Flickr.

Especially towards the end of the settlement at Çatalhöyük at an area of the site called the [West Mound](#), people there started to use pottery for their food preparation and consumption.

Here's an example of what that pottery looks like.

"Examples of calcified deposits from modern and ancient vessels at Çatalhöyük."
From [Ancient proteins from ceramic vessels at Çatalhöyük West reveal the hidden cuisine of early farmers](#), published in Nature Communications.

During the excavation, researchers noticed a kind of whitish deposit lining the inside of the pottery they were excavating. We think this is kind of like a lime scale, the kind

of mineral buildup that occurs in kettles or pipes over time. We performed a protein extraction on this lime scale. This involves a chemical extraction of food proteins that might be trapped inside that substance. We found:

- These early farmers were processing sheep and goat milk, possibly mixing them together and just occasionally using cow's milk.
- With their milk, they were also mixing in other food sources such as barley and wheat molecules. We also found proteins from what is likely [bitter vetch](#). Bitter vetch is not so well known today, but it's a kind of legume.
- Peas were used at the site as well, and not necessarily the pods. But we can actually find proteins that are specific to the seed of the pea. We can even see what kinds of parts of the plant were being used.
- We also saw evidence of meat from sheep and goat, but also from deer. Sometimes all of these things mixed together in the pottery we saw.

Ultimately, what we're able to do with this molecular information is get a sense of actually what the cuisine is like for these people living 5,000 or 6,000 years ago, which I think is really exciting.

“Changes in dairying technologies through time have selected for specialized dairy microbes”

Image credit: Niklas Hausmann/Jessica Hendy, from [Heirloom Microbes: The History and Legacy of Ancient Dairying Bacteria](#)

We also went a little bit further than this and looked more closely at those milk proteins. We wanted to see not just whether people were consuming the milk, processing the milk in these pots, but actually what *kinds* of dairy products they might have been making.

When milk is processed it typically separates into two parts: the curds and the whey. The curds are made of clumps of particular proteins called caseins and other proteins go into this whey component. The whey component is this more yellowy part, and the casein is that curds, a more white part. What we found when we looked at the proportion of these casein proteins and whey proteins, the curds and whey proteins, is that oftentimes they were mixed together. This is probably either some kind of milk or something that didn't involve the separation of these things, like a yogurt.

But in one of the pots that we analyzed, we found only this whey fraction. So this suggests that people were in fact doing some kind of separation.

It's hard to tell what those first cheeses, those first yogurts, would have looked like or what they would have tasted like. But by using techniques like this, we can try and kind of get at that question about how people were actually making these foods.

So that evidence comes from the pots that people were using for food, but what if we looked directly into people's mouths to find out what kind of dairy products they consumed?

Dental + Dairy

“Protein coverage of β -lactoglobulin identified within Eurasian archaeological dental calculus.

(a) Human dental calculus from the British Anglo-Saxon site of Norton-on-Tees (sample NEM18, ca. 6th century CE) found to contain seven β -lactoglobulin peptides. (b) Three-dimensional structure of bovine β -lactoglobulin protein, rendered from PDB 3NPO using VMD v.1.9.1³⁶. The mapped locations of all BLG peptide sequences identified by tandem mass spectrometry within archaeological dental calculus are shown in red, resulting in a coverage of 72% of the reconstructed consensus BLG protein.”

Warinner, C., Hendy, J., Speller, C. *et al.* Direct evidence of milk consumption from ancient human dental calculus. *Sci Rep* **4**, 7104 (2014).

<https://doi.org/10.1038/srep07104>

In 2014, we published a study that discovered that milk proteins preserve in dental tartar.^[3]

As plaque and in your mouth, which then becomes tartar, forms on your teeth, it's really entrapping a lot of stuff: food, bacteria that live normally in your mouth, cells from you, and even particles from the environment that are related to pollution. In extracting proteins from dental tartar, we found out that we could tell if people were drinking milk and also what kinds of species they were consuming — and this is because there are slight differences in the proteins between different animals.

▶ 0:00 / 1:33

60 Second Science, “Ancient Tooth Tartar Traps Clues to Iron Age Diet” by Christopher Intagliata, featuring Dr. Jessica Hendy, on July 24, 2018. [Scientific American Podcast](#).

This is helpful because if you're on an archaeological site and you don't find any animal skeletons, you can actually see what animals were around in the environment just by analyzing that dental tartar from the human that lived there.^[4]

Map of archaeological dental calculus samples analysed in this study. [From *Proteomic evidence of dietary sources in ancient dental calculus*](#), published in *Proceedings of the Royal Society B*.

Our study published in 2014 was focused on Europe. In more recent work we've been using this technique to find out what kinds of foods and what kinds of dairy products people were eating further East, especially focusing on Mongolia.

Mongolia + Dairy

Mongolia today has an incredibly rich dairying tradition where lots of different animals are used for milk and there are many, many different kinds of dairy products are made:⁹

- Sheep and goat are used, and often graze together in a herd.

- Horses are milked and the milk is often turned into a fermented alcohol called [Airag](#).
- Camels and yaks are milked, especially in the southern, more arid regions.
- Reindeer are milked in northern areas.

As this illustrates, there is a vast diversity of animals and products that are made by Mongolian people.^{[10](#)}

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This work, led by PhD student [Shevan Wilkin](#), of analyzing dental calculus from human skeletons across the Mongolian's history, can help us to build up a picture of what animals people used and for how long.

Around 5,000 years ago is the earliest evidence so far of people drinking milk in this part of the world. And then several thousand years later, people start to drink the milk of horses. This seems to occur at the same time that horse skulls have these morphological changes associated with horseback riding. Thus, there's something kind of important going on with horses at that time in Mongolia

Then moving into more recent time periods, we see horse milk being used in a big way. This really fits with the historical evidence at that time during the Mongol Empire, which mentions the cultural importance of this fermented horse-milk product called Airag that I've mentioned. Even at [Karakorum](#), the Mongolian capital, there was reportedly a silver fountain made by a Parisian blacksmith that flowed with Airag.

In Mongolia and elsewhere in Central and Eastern Asia, this is really interesting because there's such a strong tradition of dairying, but lactase persistence is actually very low.

There's a kind of a contradiction here: How can people be eating so much dairy food but then not have this particular genetic trait?

ANCIENT DAIRY CULTURES OF MONGOLIA

ALTERTÜMLICHE MILCHKULTUREN IN DER MONGOLEI

Much of Mongolia is covered in steppe grasslands. Dairy animals provide a way to convert this grass into edible foods for the people who live there.

Die Mongolei ist zum Großteil mit Steppe bedeckt. Milchvieh bietet den dort lebenden Menschen Möglichkeiten, die Gräservielfalt in genießbare Nahrungsmittel umzuwandeln.

People in Mongolia use the milk of many different animals, including cows, yaks, goats, reindeer, camels and horses.

Die Viehzüchter in der Mongolei verarbeiten und konsumieren die Milch von Kühen, Yaks, Ziegen, Rentieren, Kamelen und Pferden.

Many different kinds of dairy foods are made – including yogurts, dried, sour curds called *aaruul* (shown here), and even milk vodka.

Somit werden verschiedene Milchprodukte erzeugt, wie z.B. Joghurt, trockener Sauerquark names *Aaruul* (siehe Bild) und sogar Milchvodka.

The winter in Mongolia is extremely cold. Many dairy products are made during the summer to prepare for the harsh winter.

Die Winter in der Mongolei sind extrem kalt. Demnach werden Milchprodukte überwiegend im Sommer hergestellt, um sich auf den rauen Winter vorzubereiten.

Dairying is an integral part of life in Mongolia. We are working together with dairy herders, scientists and anthropologists to find out more about these unique dairy products and how they are made. Die Verarbeitung von Milch ist ein wesentlicher Lebensbestandteil in der Mongolei. Durch die Zusammenarbeit mit Viehzüchtern, Wissenschaftlern und Anthropologen wollen wir mehr über diese einzigartigen Milchprodukte und deren Produktion herausfinden.

Christina
Warinner

Matthäus
Rest

Björn
Reichhardt

Jessica
Hendy

The 'Heirloom Microbes' project investigates traditional dairying practices around the world and their unique microbial composition. More information can be found on our Facebook page; www.facebook.com/HeirloomMicrobes.

Das 'Heirloom Microbes' Projekt untersucht traditionelle Vorgehensweisen der Milchverarbeitung weltweit sowie die einzigartige mikrobielle Zusammensetzung von Milchprodukten. Weitere Informationen finden Sie auf unserer Facebook-Seite unter www.facebook.com/HeirloomMicrobes.

Photos: Jessica Hendy & Christina Warinner

“Learn about ancient dairy cultures in Mongolia and get to know our team. This is a question that's being addressed in a project called [Dairy Cultures](#), which is led by [Christina Warinner](#). This project involves looking at the bacteria and yeasts

inside these dairy products, inside the human gut, and inside the homes, a Mongolian kitchen, and determining whether it's these bacteria that are actually enabling those dairy products not just to be created, but actually be digested in the absence of that human genetic trait of lactose intolerance.

I find this such a fascinating thought that people have been able to consume a particular food for thousands of years, as we've shown through the archaeological evidence, just because of these microbial species.^{[11](#)} It also makes you think about what would happen if those microbial systems were disrupted somehow, such as if antibiotics and sterilization in this kind of food system became really, really widespread — as has perhaps likely happened elsewhere in the world that we just aren't aware of.

Scan this QR Code to
visit the Heirloom
Microbes photobook.

Knud Leem (drawing) and O.H. von Lode (copper carving). Image from [Wikimedia Commons](#).

On Discoveries and More Questions

While archaeologists would find lots of new and exciting discoveries about the world's oldest dairy products, there's still a lot that we don't know. For example, why did lactase persistence, this genetic trait, evolve in some places in the world but not others? When do people start using animals like reindeer and camels for milk? We still really don't know the answer to that basic question.

What were those early products like and what did they taste like? What kinds of bacteria and yeast were used to make them? These are questions that we're all trying to explore in some of our research and it's really a fascinating field to work in. [12](#)

[Goats milked while you wait - in a crowded market place in old Palermo, Sicily.](#) Palermo Italy, 1906. Underwood & Underwood, Publishers. Image from Library of Congress.

Footnotes

1. [The National Library of Medicine](#) and the [National Institute of Diabetes and Digestive and Kidney Diseases \(NIDDK\)](#) report between 65-68% of the worlds

population is lactose intolerant, and that “Lactose intolerance is least common among people who are from, or whose families are from, Europe.” [↵](#)

2. For more information on this discovery, please read about lead researcher Sandra Olsen’s work with [“The Early Horse Herders of Botai”](#) from the University of Kansas’s Biodiversity Institute & Natural History Museum. [↵](#)

3. To learn more about this species, please read [“The Remarkable Comeback of Przewalski’s Horse”](#) by Paige Williams from the Smithsonian Magazine. [↵](#)

4. To learn more about Dr. Hendy’s work and studies, please read [“Move over, DNA: ancient proteins are starting to reveal humanity’s history”](#) by Matthew Warren (June 2019) [↵](#)

5. To learn more about But Butters, please read [“A Brief History of Bog Butter”](#) by Jason Saley from the Smithsonian Magazine. [↵](#)

6.

For more rare findings, please read [“Secrets of Bronze Age Cheese Makers”](#) by Eric A. Powell from *Archaeology Magazine* and [“CATCH THE BUZZ – 3200 Year Old Egyptian Cheese, with Signs of Poisonous Bacteria, Would Pair Perfectly with Mad Honey!”](#) by Cassie Martin.

Additionally, read more about these studies with [“Proteomics evidence for kefir dairy in Early Bronze Age China”](#) by Yimin Yang, Anna Shevchenko, Andrea Knaust, Idelisi Abuduresule, Wenying Li, Xingjun Hu, Changsui Wang, Andrej Shevchenko (2014). [↵](#)

7. For more information about Çatalhöyük, please read [“Ancient Proteins From Unwashed Dishes Reveal the Diets of a Lost Civilization”](#) from the Smithsonian Magazine by Lorraine Boissoneault (2018). [↵](#)

8. To learn about Çatalhöyük and UNESCO World Heritage Centre, see maps and additional photographs, or explore different documents, please visit [“Neolithic Site of Çatalhöyük.”](#) [↵](#)

9. To learn more about the dairying traditions of Mongolia and efforts to improve the livelihoods of nomadic herders, please visit the [Khovsgol Dairy Project.](#) [↵](#)

10. To learn more about the history of dairying in Mongolia, please read “What Mongolia's Dairy Farmers Have To Teach Us About The Hidden History Of Microbes”

by Virginia Gewin (2020) from [Discover](#). ↵

11. To learn more about microbes, please explore “[Heirloom Microbes: The History and Legacy of Ancient Dairying Bacteria](#)” ↵

12. To keep up with Dr. Hendy’s research and the Heirloom Microbes Project, explore their [Facebook page](#). ↵

Citations

1. Earwood, C., & O’Neil, M. (1992). Two Early Historic bog butter containers. *Proceedings of the Society of Antiquaries of Scotland*, 121, 231-240. Retrieved from <http://journals.socantscot.org/index.php/psas/article/view/9410> ↵
2. Hendy, J. (2021). Ancient protein analysis in archaeology. *Science Advances*, 7(3), eabb9314. <https://doi.org/10.1126/sciadv.abb9314> ↵
3. Warinner, C., Hendy, J., Speller, C. *et al.* Direct evidence of milk consumption from ancient human dental calculus. *Sci Rep* 4, 7104 (2014). <https://doi.org/10.1038/srep07104> ↵
4. Hendy, J., Warinner, C., Bouwman, A., Collins, M. J., Fiddyment, S., Fischer, R., ... Speller, C. F. (2018). Proteomic evidence of dietary sources in ancient dental calculus. *Proceedings of the Royal Society B: Biological Sciences*, 285(1883), 20180977. <https://doi.org/10.1098/rspb.2018.0977> ↵