CHEMISTRY

A festive ferment

Harold McGee surveys a seething array of microbially transformed treats — from beard beer and grasshopper sauce to extreme herring and armpit cheese.

Rare is the holiday meal that does not owe many of its pleasures to invisible cooks with tongue-twisting names. Do you enjoy charcuterie and pickles? Bread with cultured butter? A drizzle of vinaigrette on this or that? A bit of cheese? Some chocolates? Wine, beer or cider? Then raise a glass to *Saccharomyces cerevisiae*, *Leuconostoc mesenteroides* and their ilk, the fungi and bacteria that do the real work of turning blandness into piquant delight.

As a technology rather than a metabolic mode, fermentation is the managed microbial transformation of raw plant and animal materials into foods that resist spoilage. Above all, it has been a method of preserving the bounty of a harvest or hunt for nourishment in leaner times. Peoples across the planet have applied it to nearly everything edible, from fruits, vegetables, meats and milks to animal hides in the Sudan and fish heads in the Arctic.

The most common food fermentations develop spontaneously, because the microbes responsible are ubiquitous and thrive on sugars in nutrient-rich materials such as plant tissues and animal secretions. As these first exploiters multiply, they release a number of chemical weapons that suppress their competition, and so can delay or prevent the growth of microbes that spoil foods with disgusting or toxic by-products. The weapons include antimicrobial peptides, lactic and acetic acids, and alcohols, all harmless to us in moderation and some addictively appealing. So shredded cabbage and milk readily turn sour, crushed fruits get heady, and instead of the putrid and inedible, we end up with sauerkraut, clabbered milk and wine.

Today we easily preserve raw foods simply by chilling or freezing them, which slows all biological activity. Yet fermented foods remain popular because they offer intensified, complex flavours. Stilton is more savoury than a spoonful of milk, chorizo tastier than steak tartare. The microbes themselves generate complexity by turning sugars into acids and alcohols, and by breaking down flavourless macromolecules — starch, proteins and fats — into their component sugars, amino acids and fatty acids. These building blocks have flavours of their own and serve as precursors to a host of other small molecules that we can taste or smell. The food's own enzymes can do similar flavour-generating work from within in the extended time that fermentation buys them. Eventually these changes go too far and the food becomes unappealing — effectively spoiled. That point is hard to define, and foods such as Chinese stinky tofu and Swedish surströmming, or extreme herring, delight fans by flirting with it.

MICROBIAL TEAMWORK

Food fermentations generally involve a community of various microbes growing at the same time or in succession, but it is convenient to group them loosely by dominant organisms. By far the largest group of fermentations uses the lactic acid bacteria or LAB, most of which associate with plants and secrete pleasantly tart lactic acid. The LAB produce an impressive array of our favourite foods. Among them are yogurt,

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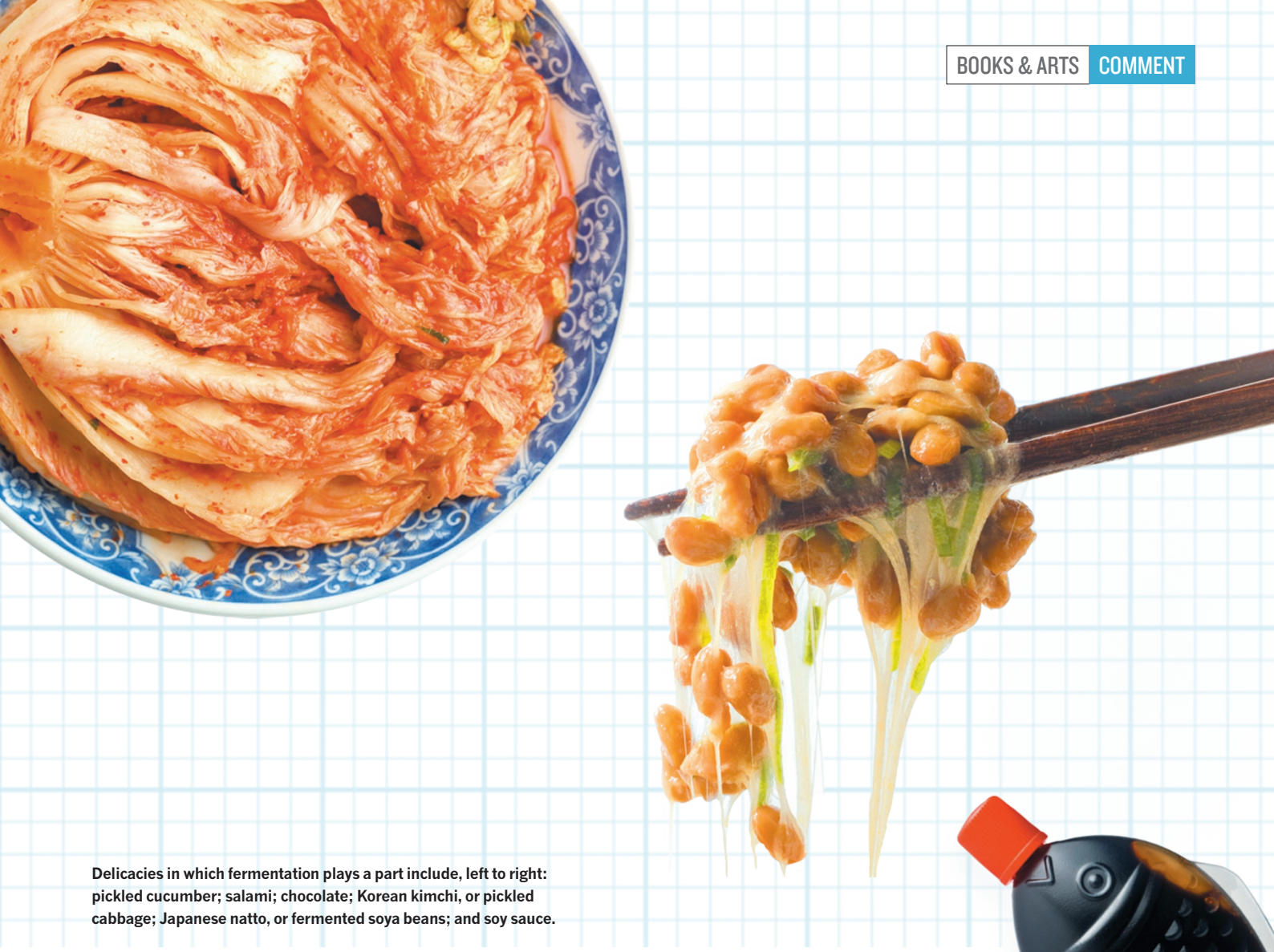

Delicacies in which fermentation plays a part include, left to right: pickled cucumber; salami; chocolate; Korean kimchi, or pickled cabbage; Japanese natto, or fermented soya beans; and soy sauce.

cheese and cultured creams such as crème fraiche; sauerkraut, Korean kimchi and other pickled vegetables; dry-cured salamis and similar sausages; Asian fish sauces; and the rice–lentil batters for two South Indian and Sri Lankan specialities, the crêpe-like dosa and plump idli.

A second main group of food fermentations stems from the yeasts, pre-eminently *S. cerevisiae*, which produce alcohols and carbon dioxide from fruit juices and other sugar-rich liquids: hence wine and beer and their distillates, brandies and whiskies. If given the chance, certain bacteria will feed on alcohol, produce acetic acid, and turn wine into vinegar — or transform bland and astringent cocoa beans in their fermented fruit pulp into the makings of richly flavoured chocolate. In thick doughs and batters made from grain, which contain enough sugar to support only limited yeast growth, the alcohols get cooked out and it is the gas that matters. It turns the dense mass into a light foam with a structure that is stabilized by heat to make leavened breads, from Ethiopian injera to Italian panettone.

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A third group is based on an Asian method for fermenting starchy foods, mainly the seeds of grains and legumes, which yeasts and LAB cannot utilize directly. Some time before the second century BC, Chinese brewers domesticated a species of *Aspergillus* mould to convert the starch into fermentable sugars, at the same time generating its own distinctive aromas. It is with the help of this *Aspergillus* culture, called *qu* in China and *koji* in Japan, that sake and other alcohols are made from rice. It is also how miso paste and soy sauces including tamari are made from soya beans and grains. Because Western brewers have always prepared grains very differently, by 'malting' or partly germinating them to develop their own starch-digesting enzymes, the *koji* fermentation has been little known outside Asia until the past decade.

MODERN REVIVAL

Today's manufactured versions of fermented foods are often just approximated: many 'pickles' are just vegetables drenched in acids such as vinegar. But do-it-yourselfers have kept home fermentation alive, and in recent years foodies and artisans have been rediscovering its magic. Pickles and vinegars are especially straightforward to craft, and their variations and labels seem to be growing logarithmically — as is the baffling popularity of kombucha, sweetened tea fermented with what is known among enthusiasts as a SCOBY. These symbiotic communities of bacteria and yeasts are solid cellulosic aggregates that have been found to include as many as 20 microbial genera. In my experience, too many cooks. I am partial to flavoured sauerkrauts (beets and ginger, Indian spices) and local fresh natto, soya beans fermented and made slimy by *Bacillus subtilis*, much superior to frozen imports.

Professional cooks have also caught the fermenting bug, with restaurants now proudly offering their own distinctive pickles and cured meats. And a handful of programmatically innovative restaurants have successfully adapted *koji* fermentation ▶

to Western ingredients. In New York City, the Momofuku restaurant group's Culinary Lab has focused on miso- and tamari-like pastes and sauces made from non-soya bases such as cashews, pistachios, chickpeas and spelt. Copenhagen's renowned Noma and the affiliated Nordic Food Lab have had good results with a yellow-pea 'peaso', a barley *koji* roasted to a chocolate brown and versions of fish sauces made from grasshoppers and from *koji*-treated beef.

These experiments with fusion fermentation are probably just a taste of things to come. The James Beard Foundation, a New York-based organization of professional chefs, gave its award for the best reference book of 2013 to Sandor Ellix Katz's 500-page *The Art of Fermentation* (Chelsea Green Publishing), a jaw-dropping survey of possibilities from abará (Nigerian steamed or boiled fermented cowpeas) to zur (Polish sour rye porridge soup).

"Provocation rather than flavour has motivated experiments with what might be called personal fermentation."

Outside the restaurant world, provocation rather than flavour has motivated experiments with what might be called personal fermentation. After the Rogue Ales brewery in Newport, Oregon, failed to find beerworthy wild yeasts in its hop yard, it turned to a different local niche: a strain cultured from the brewmaster's hair follicles now goes into the making of its speciality Beard Beer. And noting that we regularly devastate our own microbiome to suppress its production of the same odours that we enjoy in fermented foods, biologist Christina Agapakis and artist Sissel Tolaas have developed an exhibit to help us to better appreciate our unsanitized selves: cheeses made from milk inoculated with swabs of volunteers' hands, feet, noses and armpits (see A. King *Nature* **503,** 196; 2013).

After a centuries-long stationary phase during which traditional food cultures slowly developed in isolation from each other, the world crock has been stirred and things are really bubbling. Will new fermentations grace our future holiday spreads? Even the possibility is worth toasting. ■

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