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Sudanese Fermented Foods

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Abstract

Fermented foods of Sudan are a great source of affordable daily nutrition for many families and age groups all over the country. These foods include a diverse categorisation of starting ingredients and incur traditional methodologies of production which have been preserved for centuries. We used next generation sequencing (16S rRNA and 18S rRNA) to analyse 44 Sudanese Fermented foods in five major categories food types; sorghum, plant, meat, fish and dairy. Samples were collected in Khartoum, Sudan and analysed in Cork, Ireland. We found an extensive array of unique microorganisms in Sudanese fermented foods that extended over 1300 operational taxonomic units (bacterial identification) and many fungi. While many of these foods have healthy benefits for human health, harmful bacteria and fungi were also found owing to the preparatory methods of these types of food. Further research is required to isolate the microbiome of such foods and bring about health promoting effects of Sudanese Fermented Foods to light.

Keywords: Sudan, fermented foods, 16S rRNA sequencing, Sudanese foods.

Introduction

Fermented foods are often consumed worldwide, and in Ireland, some of the most typically eaten fermented foods include cheeses, yoghurts, and salami. In the culturally distinct population of Sudan fermented foods are a great source of affordable daily nutrition for many families and age groups. In Sudan, fermented foods initiate from a diverse categorisation of starting ingredients, including dairy products, meats, fish, seeds, fruit, and vegetables. Preparation of these foods incurs traditional methodologies of production that have been preserved for cen-

turies. These foods are widely influenced by the diverse ethnic backgrounds of the Sudanese people as well as environmental factors such as seasonal changes, the economic stability of the regions as well as migration and internal displacement of people.

Consumption of various fermented foods has been shown to exert many benefits in the human body, such as preventing atherosclerosis and reducing blood pressure and cholesterol levels. In addition, fermented foods are now thought to have an ever-increasing role in protecting against diabetes, infections, and cancer.

What are the types of food fermentation in Sudan?

Fermentation is an essential metabolic process that develops by the action of fungi and bacteria. Fermentation can occur both aerobically (in the presence of oxygen) or anaerobically (without oxygen), with the latter being more common. Due to the hot weather of Sudan, many fermented foods begin by aerobic fermentation under natural heat for a short time. The products are then transferred to airtight containers to achieve anaerobic fermentation, which produces many substances that help modify the foods' original texture, taste, and function. Other foods are fermented through anaerobic fermentation which may even occur underground in Sudan. Fermentation preserves nutrients and allows foods to be stored for more extended periods, a significant feature in times of drought that offers nutritious resources for parts of the population who are impoverished in Sudan.

Microbiome of Sudanese fermented foods

The microbiome refers to all the microorganisms in any given environment, including the human body, animals, soil, and foods. The microbiome also involves understanding various roles of these microorganisms in their environment, such as how they interact with each other, their products and genetic material. Our research analysed for the first time the microbiome and mycobiome (fungal analysis) of Sudanese fermented foods that have not been undertaken in Sudan. For microbiome analysis, next-generation sequencing (a novel method for detecting microorganisms) is involved that allows the identification of many unique microorganisms. We wanted to understand the types of bacteria and fungi that were present in the various Sudanese fermented foods.

How many samples were analysed, and where were they collected from?

We collected 44 samples in total from Sudan, Africa. We visited various homes of Sudanese people from western, eastern and central Sudan (Khartoum). We went to the most common open-air markets where fermented foods are sold in the cities of Khartoum and Omdurman. We collected samples when they were fresh and kept them under normal conditions as much as possible. We achieved sample analysis in APC Microbiome Ireland, Cork, Ireland.

Figure 1

What types of food were analysed?

We chose the most consumed fermented foods (and drinks) around Sudan. We included bread like sorghum pancake (Kisra) (Figure 1a) which is a staple food and often used instead of bread. The sorghum fermented product (red Abreh) consumed as a juice with a bittersweet flavour and a product called Damirga said to have local healing properties against dehydration and diarrhoea were also studied. We analysed the food 'Kawal' (Figure 1b) made from the fermentation of the *Cassia obtusifolia* plant. Three fermented fish products were included in our research: moist fish (Faseekh), small (Mendeshi) (Figure 1c) and large fermented (Kajeik) fish (Figure 1d). Air dried meat (Shermout), fat sheath fermented product (Miriss) and intestine (Musran) were also included in this research (Figures 1e, 1f and 1g). Finally, an important category was dairy products which included yoghurt (mish) (Figure 1h) and fermented camel milk (Garis). For some foods, we analysed them during the preparatory stages as well as the final product

What were the results?

We found an extensive array of unique microorganisms in Sudanese fermented foods. Many of these are healthy or 'probiotic' bacteria such as *Lactobacillus* that are also found in many yoghurts and cheeses in western cultures. Many sorghum-related samples had a bacterium more common to fermented foods in Africa; *Weissella*, which, apart from its fermentative properties, may also help prevent spoilage from food-borne pathogens. Indeed, an important observation is the excellent keeping qualities that such bacteria allow, making Sudanese fermented foods last in excellent condition for over a year.

In the samples of Kawal that are predominantly consumed amongst those from western Sudan, we found a microbiome consisting of many probiotic bacteria (*Lactobacillus*, *Bacillus*) as well as *Pediococcus*, a bacterium also found in fermented cabbage (sauerkraut). Many bacteria

Food type	Fungal identities (genera)
Kawal	Over 80
Fish	40
Garis (camel milk)	20
Miriss (fat sheath)	11
Sorghum	8

Table 1

and fungi found amongst Sudanese fermented foods samples were tolerant to harsh conditions, such as the bacteria *Bacillus* which produce spores that help them survive. During drought conditions, these foods can offer favourable nutritional value to their consumers. After baking some fermented foods, the introduction of bacteria such as *Streptococcus* is likely introduced during the food's preparation.

In our research, we found that some of the Sudanese fermented foods had an extensive richness in fungal species that could provide benefits in preventing diarrhoea, improving digestion and reducing proteins that cause allergies in the diet. The Kawal samples had the most abundant number of fungi, followed by one of the fish samples. Table 1 highlights just how many fungi were found in the various groups of fermented foods in order of high to low abundance. These fungi varied in distribution among the different fermented foods; for example, in Kawal samples, *Issatchenkia* were the most abundant, in the Garis camel milk, it was *Kluyvermyces*, and in the fermented fish product, *Aspergillus* was found to be the most common fungi.

In the fish samples, some bacteria that were predominant were found to be resistant to cold conditions (*Sporosarcina*) and could relate to the specific environments of the river Nile fresh water.

Many of the microorganisms in Sudanese fermented foods owe an important contribution to the taste and texture of the final product. Examples included *Kurthia*, found amongst the fish microbiome, which produces tainting flavours to fish and meat. The fat sheath product; Miriss was abundant in the bacteria; *Bacteroides* and *Lysinibacillus* (although not all samples had equal quantities). Garis samples were abundant in the fungus *Kluyveromyces* that can ferment sugars at high temperatures contributing to the drink's flavour. Finally, the fungi *Wickerhamiella* unique to the Garis camel milk samples are also known to contribute to specific flavours in soy sauce.

Benefits of consuming fermented foods include improved digestion, vitamin production and maintenance of healthy body weight. While many bacteria (and fungi) found in Sudanese fermented foods were found to contribute positively to human health, it was also found that the microbiome of these foods does contain potentially harmful microorganisms. These are most likely introduced during the direct hand use and open-air fermentation during these foods' preparations. For example, bacteria such as *Clostridium* and *Enterobacter* were found in several samples and can cause diarrheal disease, while *Ignatzschineria* is associated with larvae of fresh flies and was found amongst the Miriss fat sheath samples. The most abun-

dant bacterium amongst the Musran fermented intestine was *Escherichia shigella*, known to cause dysentery. Species of *Cronobacter* were appreciated amongst the Garis camel fermented milk that is known to be a food-borne pathogen. *Cronobacter* can further thrive in hot and dry environmental conditions.

Future directions and conclusions

While this is the first study to target the understanding of the microbiome of Sudanese fermented foods through novel scientific methods, it will by no means be the last. Our research intends to be the stepping stone for both our team and future researchers in understanding how microorganisms help develop fermented foods. It is important to work with the Sudanese people in finding common ground to both promote the heritage of Sudanese fermented food production whilst also utilising safe and non-contaminated food preparatory techniques that limit food-borne diseases throughout their communities.

This is even particularly important for a country such as Sudan, where a large part of the population cannot afford medical treatment or purchase emergency drug prescriptions. It is imperative, therefore, that Sudanese fermented foods continue to harbour beneficial microorganisms in tandem with positive connections to human health rather than impact negatively by spreading disease. Another important future path is the isolation of safe bacteria from Sudanese fermented foods to produce them under controlled and sterile conditions for probiotic dietary supplementation. Such products can even be adopted worldwide, including in Ireland.

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