

Lutefisk: Secrets of the Taste, Texture, and Aroma Revealed by Scanning Electron Microscopy

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Introduction

Lutefisk (lyefish) is a traditional delicacy that today is generally served as an Advent celebration treat for the whole family, but was once a staple of Scandinavian diets. During the late 1800s and early 1900s, Scandinavian immigrants brought traditional foods like lutefisk to the USA. The focus of this paper is on secrets of lutefisk but is based primarily on anecdotal data from Minnesota; however, we fully expect the data to represent Scandinavian immigrant communities through North America. Children growing up in rural Minnesota spend the year in anticipation of this seasonal feast. This seasonal delicacy is commonly found in all fine markets from October through December in areas where large numbers of people of Scandinavian descent live. The testimonials of true lutefisk eaters are all you need to dish up and dive in. For example:

"Can you pass that bowl of lutefisk again? I need another plate." (Fritz Larson, personal communication.)

"Elsie, are you having lutefisk again tomorrow? I am free." (Edla Mooers, personal communication.)

However, not everyone has a tolerance for the fine taste and aroma of this culinary delicacy (see *Lutefisk Lament* by Boone and Erickson or *Oh, Lutefisk* by Stangland and Lee). Keillor (1990) sums up the thoughts of many as follows:

Every Advent we entered the purgatory of lutefisk, a repulsive gelatinous fishlike dish that tasted of soap and gave off an odor that would gag a goat. We did this in honor of Norwegian ancestors, much as if survivors of a famine might celebrate their deliverance by feasting on elm bark. I always felt the cold creeps as Advent approached, knowing that this dread delicacy would be put before me and I'd be told, "Just have a little." Eating a little was like vomiting a little, just as bad as a lot.

After years of tabulating anecdotal evidence, the authors have identified a correlation between the preparation and cooking methods of lutefisk and the general tolerance of lutefisk eaters. To elucidate the underlying biochemistry, scanning electron microscopy was employed. Following a successful lutefisk offering at a Department of Geological Sciences holiday potluck dinner, sample of the lutefisk were immediately imaged with SEM.

The results were surprising and unexpected. Lutefisk has a unique texture that is dominated by 3 distinct cellular structures. Herein we refer to these as **flavor cells**, **texture cells**, and **aroma cells**, and speculate on the relation to preparation and cooking methods.



Figure 1A:
Drying cod on racks in Norway

Figure 1B:
Method of reconstituting lutefisk.

Background

Drying and Reconstituting Lutefisk – Prior to the general availability of refrigeration, fish was preserved by drying (Figure 1A). Types of fish and the drying methods varied by location and cultural tradition but generally drying was accomplished on racks by the Sun, cold dry air, or wind. Once dry, the fish could be stored for long periods of time while being shipped to local or distant markets. Dried fish is then consumed directly or it can be reconstituted by rehydration. In Scandinavia, the most readily available types of commercially available fish were cod, haddock, whiting, and torsk (en.wikipedia.org/wiki/List_of_fish_in_Sweden).

Although there are a number of methods for reconstituting dried fish, lutefisk is prepared from the dried fish in a very specific multi-step process. The first step is to soak the dried fish in a lye solution for several days with frequent changes of the water (Figure 1B). The lye solution breaks down the tough dried cellular structure created by the drying process; it also reduces the protein content. Care must be taken not to let the lye treatment go on too long because saponification may occur and convert lipids to soap (Bodenstein 1961). When prepared correctly, the result is a gelatinous substance with a pH of about 12 that quite resembles fish. The next step is to rinse the lye from the fish by soaking for several days in fresh water with at least daily water changes. After these final rinses the lutefisk is ready for delivery to markets.

Traditionally, lutefisk was delivered dry to markets. Once there it was stacked like cordwood on tables or, alternatively, leaned against the side of the market on the sidewalk. There was no need for great care in the storage because the impending lye treatment would eliminate any living matter. D. E. Mooers (personal communication) often described the stacked lutefisk as a common stop for dogs.

Preparation and Cooking of Lutefisk – Once reconstituted, lutefisk is purchased and brought home. Great care must be taken at this point to store the lutefisk in air-tight containers or an adjacent building as the odor of fishy-lye can be pungent (Keillor 1990).

To prepare for cooking, the lutefisk is again rinsed thoroughly. Although cooking methods vary, each traditional Scandinavian cook has their favorite:

Steaming – Lutefisk is salted, placed in a tightly-covered pan, and steamed in its own liquid for 20 minutes or so.

Baking – Lutefisk is placed in a baking dish (often lined with aluminum foil) and baked at 250°F – 300°F for 40 minutes or so.

Boiling – Water is brought to a rolling boil and lutefisk, cut into small pieces, is placed in the boiling water. Return the water to a boil and cook for 5-8 minutes. Care must be taken not to overcook as the lutefisk will fall apart.

Eating – Once cooked by any method, the lutefisk is ready for serving. Traditionally the white gelatinous fish is served over mashed potatoes and covered in white sauce with melted white butter. The only allowable seasonings are salt and pepper; the pepper gives the meal color.

Methods

Methodology for this investigation consists of compiling anecdotal data on lutefisk eaters, cooking method, and the comments of adjacent non-lutefisk eaters. These data were compiled mainly from dinner napkins and back-of-the-hand scribbles.

Determination of cellular structure of the lutefisk was determined by SEM. Samples were taken from leftovers after a departmental holiday potluck dinner. Lutefisk served as the main course surrounded by a variety of hot dish offerings. Samples were mounted and loaded into a JEOL JSM-6490LV variable pressure scanning electron microscope. Samples were scanned at low vacuum so that they could be left wet to preserve the edible nature of the samples.

Results

41 years of anecdotal data are compiled in Table 1. Comments were recorded in many forms but broken down into several main comments. These comments were then translated by one of the authors (HM) into the 3 main categories. For lutefisk lovers' comments the 3 categories are: Pretty Good, You Betcha, and Uffda. The bystanders comments are also broken into 3 categories: Just Dizzy, a series of gagging sounds, and Uffda (Uffda can be used as a superlative for both positive and negative comments). A summary of the results for each cooking method are tabulated in Table 2 and represented graphically in Figure 2.

Lutefisk lovers' comment	Translation
Aw Geez	Pretty Good
Oh don't ya know	Pretty Good
Pretty Good	Pretty Good
You Betcha	You Betcha
Uffda	Uffda
OMG	Uffda
LOL	You Betcha

Bystanders' comments	Translation
Not fit for Man nor Beast	Just Dizzy
[speechless]	Uffda
[heard through bathroom door]	Uffda
Uffda	Uffda
Argh	Gagging
Ahem ...	Just Dizzy
Not as bad as last year	Just Dizzy
Humph	Gagging

Table 2. Cooking preference

Lutefisk Lovers' Response	Steaming	Baking	Boiling
Pretty Good	89%	78%	14%
You Betcha	8%	17%	29%
Uffda	3%	5%	57%

Bystanders' Response	Steaming	Baking	Boiling
Just Dizzy	4%	8%	64%
Gagging	10%	10%	26%
Uffda	86%	82%	10%

Scanning electron micrographs are shown in Figure 3. Figure 3A is a 350x magnification of a fish fiber. Increasing the magnification to 2500x instantly reveals 3 types of cellular structure (Figure 3B). The dense fish fiber in the center of Figure 3B can be distinguished from the 2 other textures by its more massive appearance. Cells on either side are more open

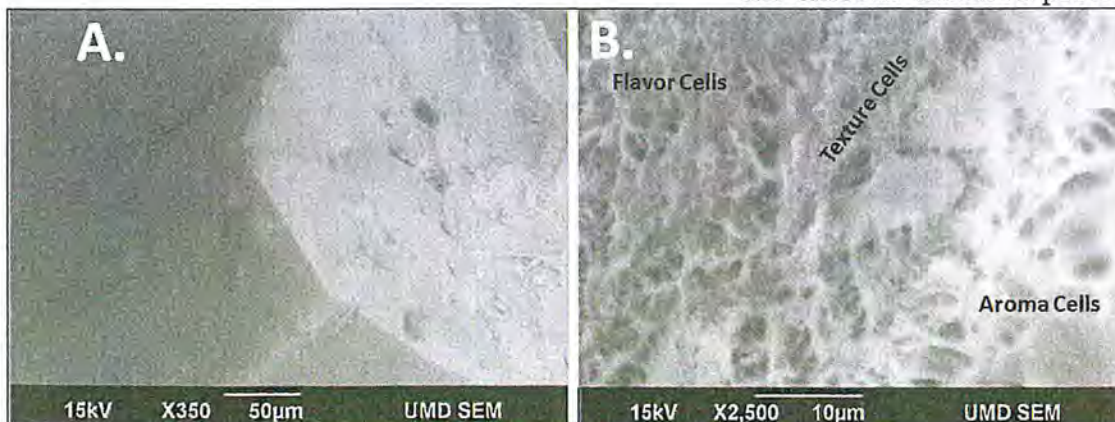


Figure 3A. 350x enlargement of lutefisk fiber.

3B. 2500x enlargement of lutefisk showing the texture, flavor, and aroma cell locations.

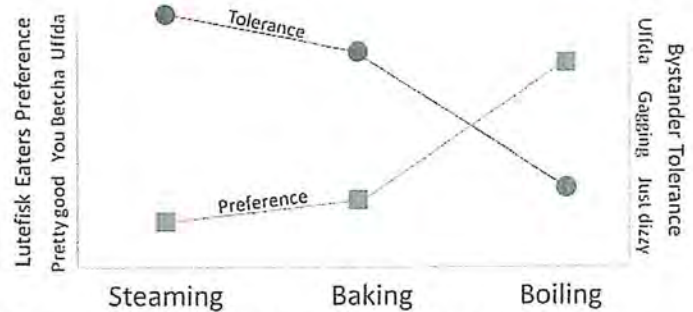


Figure 2. Summary of data from Table 2.

and contain vacuoles. However, among the cells outside the massive zone there are 2 distinct textures. On the left of Figure 3B is a network of fibrous protein with irregular vacuoles. On the right side of Figure 3B is an area of smooth textured protein with large round vacuoles.

Discussion

Although the data are anecdotal there is a clear correlation between cooking method and both lutefisk lover and bystander response. Uffda responses by lutefisk lovers are far more common with the boiling method of cooking than either steaming or baking (Figure 2), whereas Uffda responses by bystanders are most common with steaming or baking (Figure 2).

These data can now be interpreted within the context of the cellular structure of the lutefisk. We interpret the dense fish fiber to be the *texture cells* (Figure 3B). These are the cells that give the lutefisk its unmistakable gelatinous texture. The network of fibrous protein with irregular vacuoles is interpreted as the *flavor cells* (Figure 3B). These cells likely release the portion of the lutefisk that brings pleasure (You Betcha or Uffda response) to lutefisk lovers. The large round open cells of the smooth-textured protein are unmistakably

the cells that produce the pungent aroma (*aroma cells*) of lutefisk (Figure 3B).

Further analysis of the texture, flavor, and aroma cells indicates that each cellular structure behaves differently depending on the pretreatment and cooking method. No matter how much you rinse the lutefisk there is still a mass of remnant lye contained in the aroma cells. This aroma cell lye is quickly volatilized by cooking the lutefisk by steaming or baking. Apparently, the cells open quickly under heat, and without a protective water jacket escape quickly to the air and are transported by diffusion and advection to the surroundings. Evidence suggests that volumes of air equal to an entire Lutheran Church, or even that above a frozen lake on a cold December day with a

North wind, can be contaminated. Utilizing the boiling method of cooking insulates the escaping volatilized lye with a water jacket. There is apparently a residence time of the lye in the water that exceeds several hours. However, this water should never be left overnight and should be contained and driven to a neutral location for disposal.

Summary

Boiling the lutefisk is the clear choice of both lutefisk lovers and bystanders. Although we do not claim to have uncovered the true biochemical mechanism controlling the flavor of lutefisk, we do provide evidence that the cellular structure plays an important role.

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My Life as an Electron

Dick Mead, Baltimore

As an electron I have always been attracted to protons. It is not clear to me why I feel this attraction but I've been told it's the law. Of course, there are protons and there are protons. With the wrong proton, life can be dismal to say the least; but I was lucky to spend several years with a proton with a heart of gold, and I can tell you those were the best years of my life.

It was a continual mad whirl, dancing around and around; he in the center, me in a very stable state doing the circles. The fact that a neutron was always hanging around did not dampen our enthusiasm.

I dreamed of recapturing that life. Until the day before yesterday I had given up all hope of ever again finding that level of ecstasy.

I was on a very average flight from here to there. I was traveling at about $0.6c$ and

enjoying the gentle pulls of the various fields that one so frequently encounters, when a tiny speck, a particle, came into view. I adjusted my flight to cross paths with this interesting and intriguing particle. The closer I came the more I realized that the other particle resembled myself, but with an unfathomable yet perceived profound difference.

As we approached, a strange desire erupted within me. **As we came together there was a sudden flash and before I could say "Albert Einstein" we had become no more, and in our place, speeding out in opposite directions at $1c$, were 2 of the most beautiful rays I have ever seen.** Of course, my new companion and I no longer existed in the strict sense of the word, but somehow we knew that what we had done was good!