Can dried seaweed get moldy? A pictorial guide.

Customers sometimes contact us with concern that their seaweed has mold on it. They may even send along images of the suspected mold to get our opinion. More often than not, we reassure them that what they are observing is just natural mineral salts and sugars that crystallized on the surface of the sea vegetable as it dried. Sugars and mineral salts help heighten seaweed's umami flavor and sea vegetables often arrive with at least some trace of this "umami powder." Since sea vegetables may continue to lose moisture after purchase, more powder can develop over time and fool people into thinking the seaweed is growing moldy (Figure 1). Many times, salts and sugars precipitate not as powder but as crystalline, web like structures that can look a lot like mold.

Figure 1. Dried sugar kelp (top) and dulse (bottom) with precipitated salts and sugars

This does not mean mold never occurs on dried seaweed, though. Mold is a tenacious organism capable of growing on almost any organic substrate, even under the most challenging of conditions. Should people be concerned about moldy seaweed? How can one tell the difference between mold on seaweed and something else such as salts and sugars? Is it safe to eat seaweed if it has mold on it? How is mold prevented? Although we address mold in our FAQs, some people may want a better understanding of the issue. Read on to get answers to these and other moldy questions.

What is mold?

Mold is formed by certain species of fungi for reproduction, though not all fungi produce mold. Some fungi produce mushrooms for the same purpose. Fungi grow as cylindrical, thread-like branching structures known as hyphae that spread through organic matter and release chemicals to break it down into nutrients for their growth. Hyphae form networks called a mycelium, which forms the thallus (body) of the fungus and which can then develop into reproductive structures such as mold or mushrooms for spore dispersal. Under the microscope mold appears as stalks, known as sporangiophores, with an oval or rounded sporangium containing reproductive spores (Figure 2). Molds come in an array of colors including white, black, gray, brown, blue, yellow, orange, and green.

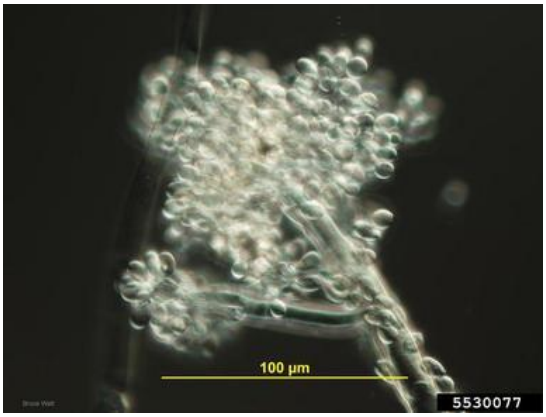

Figure 2. Gray mold. *Photo by Bruce Watts, University of Maine, Bugwood.org*

Fungi, mold, and yeasts are placed within a single group of related organisms named the *Eumycota* having a common evolutionary ancestor. There are an estimated 2-3 million different species of fungi, but only about 480,000 have been described. Fungi are natures' principal decomposers, though many species form symbiotic or parasitic relationships with living organisms. Most fungi are small and inconspicuous, living out their lives hidden from view in soil, wood, plants, and other organic matter, but some fungi can grow into enormous organisms. In fact, the world's largest organism is said to be a single fungal colony of *Armillaria ostoyae* covering more than 3.4 square miles in an Oregon forest!

Is mold dangerous?

Although most fungi and molds are harmless, some are mildly allergenic and others produce mycotoxins. Mycotoxins can make people extremely ill and in rare cases even lead to death, but so far, no mycotoxins have been associated with dried seaweed. Most food molds are generally regarded as spoilage organisms. When mold grows on bread, dairy products, fruit, vegetables, and other foods, it is usually considered sufficient cause to discard the food. Food preservation strategies such as drying, freezing, canning, salting, sugaring (as in jams) and pickling are all designed, in part, to thwart mold growth.

Not all mold is bad for food, however. Brie and blue cheese get their distinctive flavors from *Penicillium* molds, and some sausages, such as salami, use mold starter cultures to improve flavor and reduce bacterial spoilage during curing. The mold is often visible on the salami as a powdery white coating. Fungi also play an essential role in chocolate making. Cacao beans must be fermented to remove their bitter taste and break them down. This takes place with two types of fungi: *Candida krusei* and

Geotrichum. These are often naturally present on the beans but chocolate makers may use specific strains that have been carefully selected to optimize flavor. An especially interesting group of culinary molds are the Kōji molds from the *Aspergillus* species, which have been cultured in Japan for centuries. Kōji molds are used to ferment rice, soybeans, or wheat to create paste (miso) and soy sauce; in the production of sake, shōchū and other distilled spirits; and to prepare Katsuobushi, a fermented, smoked, and simmered skipjack tuna product also known as bonito flakes. Recently, a process was described that uses Kōji molds to produce a fermented flavoring sauce from nori seaweed.

Mold and seaweed

Mold is normally associated with moisture and soft foods like bread and cheese. Dry, hard seaweed seems like an unlikely environment for it to grow, and indeed it is. However, we know from years of testing dried seaweed for microbial safety that it is not uncommon to find small numbers of mold and yeast spores associated with it. Of course, the same is true of almost every raw, unsterilized food one can name. Fungi are everywhere and their spores easily travel to colonize new places. Raw carrots, lettuce, wheat flour…you name it, it contains mold. In fact, microbiological standards for most food products, including dried seaweed, allow for some mold and yeast to be present. Whether you like it or not, you probably eat mold spores every day.

The issues are really ones of abundance, food quality, and safety. When mold colonies grow on food you can be certain that fungal hyphae have invaded the food matrix. In doing so they release digestive enzymes that break the food down. Fungal growth often indicates the food is past its “best before” date and/or has been exposed to moisture or warmth, both of which degrade quality and are conducive to the growth of spoilage bacteria and even pathogens.

However, the story isn’t quite so simple when it comes to dried seaweed. Common mold species that grow on foods such as bread and fruit are incapable of growing on dried seaweed, because it simply does not have enough available water content and is too salty to support growth of these fungi. This means that spores released by moldy bread or a container of sour cream are highly unlikely to contaminate and grow upon dried seaweed.

The natural fungal flora associated with seaweed in the environment has not been well studied, although numerous saprophytic (feed upon vegetative matter), parasitic, pathogenic (to the seaweed, not to humans), and symbiotic fungi have been reported for seaweeds. Most are adapted for growth on live or decomposing seaweed and would probably not grow very well, if at all, once the seaweed is harvested and dried. The scientific literature contains few references regarding fungi and seaweed and practically no information regarding fungi on dried seaweed. An article printed in 1967 describes the brown mold species *Sporendonema minutum* growing on dried rockweed meal. Crucially, the important consideration highlighted in the article was that this fungus was found only on seaweed exposed to overly moist conditions that increased its water content to over 25%.

How does moisture content control mold growth?

Drying is an ancient and effective food preservation method that reduces moisture content and thus the amount of water available to microorganisms for growth. Water in food which is unbound to food molecules (aka free water) is available to bacteria and fungi (yeast & mold) for growth. Water activity (a_w) is a measure of this unbound water, and the scale goes from 0 to 1, with dry as dust being 0 and pure water being 1. Most bacteria cannot grow below .9 and most molds cannot grow below .8. Even a

seemingly watery food, such as jam, may lack enough free water to support the growth of food pathogens, because some of it is bound to sugar molecules. Most jams and jellies have an a_w of .8 or less. Bread, on the other hand, typically has a water activity of .95, which is why it so easily grows mold.

Drying seaweed is the crucial process control step that stops almost every fungus and other microbe in its tracks. As seaweed is dried, more and more of its unbound water is lost through evaporation, leaving behind a larger proportion of bound water. Properly dried seaweed should have <25% moisture, and most of our products contain <20% moisture. The water activity of our dried seaweed generally falls between .16 and .66 and about 70% of our products are below .6, the threshold where nothing can grow, not even the toughest of molds. We have instruments that measure moisture content and water activity to help us meet these standards. However, there are some molds that can survive water activity as low as .61. Organisms that can survive and grow at such low available water are known as extreme xerophiles (from Greek xēros 'dry', and philos 'loving'). They are not especially common and for the most part they tend to grow slowly or remain inconspicuous for a long time.

The chances are good that any mold found on dried seaweed from the package grew before or while it was being dried. Mold can develop when drying gets interrupted by a humid stretch or other environmental factors that prolong drying. As drying continues, any mold colonies growing on it dry out and become inactivated, but the dried, inert mold remains attached. We carefully hand-grade dried seaweed at our processing plant to remove anything that we ourselves would not care to eat, but occasionally (rarely!) stray fronds with dried out mold on them may slip through. So long as the seaweed remains dry it should not support any further mold growth. However, dried seaweed is very hydroscopic and if the seaweed is left in an opened container in a humid environment or otherwise exposed to moisture, it can quickly absorb enough water to support mold growth. Dried seaweed should always be stored in a closed, air-tight container at room temperature, and not in the refrigerator.

How can I tell if it is really mold?

At this point it should be clear that dried seaweed is quite inhospitable to mold growth, let alone in profuse abundance. This is why most of the time we can reassure customers that what they are observing is not mold, but precipitated salts and sugars. Dried seaweed contains various mineral salts such as sodium, magnesium, potassium, calcium, phosphorous, and iron, along with sugars such as mannitol. As the seaweed dries these salts and sugars precipitate on its surface to form intricate, latticelike, or powdery crystalline structures that, to the naked eye, may appear fuzzy, much like mold. They can also appear as a flat scale, and they can coat the entire surface or manifest as random patches. Salts and sugars bring umami and a subtle sweetness to dried seaweed, so most people choose to leave them on, but they can be easily brushed or rinsed off just prior to use if desired. Figure 3 shows a classic example of sugar kelp with precipitated salts and sugars.

Figure 3. Sugar kelp with a powdery coating of salts and sugars. This can be rinsed off but better left on for maximum umami flavor.

Figure 4 shows dulse with precipitated salts. The green patches are areas of underlying chlorophyl pigment. Dulse blades sometimes have small patches of microalgae growing upon them that turn gray when the dulse is dried. These can also be mistaken as mold, but they are totally harmless.

Figure 4. Dried dulse with a small patch of precipitated mineral salts

Now, we know no one wants to eat mold, but on the other hand, no one wants to return perfectly good seaweed or throw it away. This is probably one reason why some customers go through the trouble of sending photos. However, there are a few simple signs and observations that can help one determine whether dried seaweed is moldy or not. Sugar kelp leaf, Alaria leaf, and dulse leaf are the three species that most commonly elicit concern.

The first thing to determine is whether the product was exposed to too much moisture. Was it left in an open container or humid environment? Refrigerators can be quite humid, which is one reason why we

advise against refrigerating dried seaweed. If the answer is no and the seaweed comes out of the container in a dry or even brittle condition, then it is highly unlikely to support mold growth. However, some of our products, such as dulse, may have a supple texture that can make them appear somewhat moist, even though they are probably quite dry (<25% moisture). In these cases, it can be difficult for customers to know if the seaweed contains enough available water to support mold.

Another useful feature is color. White patches are usually salts and sugars but yellow, brown, or gray patches should be subject to more scrutiny. In Figure 5, we see an example of sugar kelp with brown, white, and grayish patches. The brown spots are mold, whereas the white areas are probably salts and sugars. Some of the patches are grayish, but regardless, the brown spots alone mean the product should not be consumed. Figure 6 shows an example of dulse with a brownish-gray mold.

Figure 5. Sugar kelp with dried colonies of brown mold

Figure 6. Example of moldy dulse. Note the grayish, brown, and extremely fuzzy patches. Not very appetizing! In this case the white could either be mold or precipitated salts.

If the material is white but your still in doubt, try adding a few drops of lukewarm water to one of the suspect patches. If the white material dissolves, then it is certainly mineral salts and/or sugars. If it does not dissolve, next try adding a few drops of vinegar. Calcium and magnesium salts do not readily dissolve in water, but they will dissolve in an acidic solution such as vinegar. Mold, however, will not dissolve in either one. When using this method, it may work better to scrape some of the suspect material into a small bowl before adding the water or vinegar.

One final observation: Our sea vegetables are wild, naturally growing, marine organisms. Even though they are dried they are still a minimally processed whole raw food. For most people this is a major attraction but it also means that dried seaweed may arrive with things attached to it that are most definitely not mold. Organisms such as barnacles and bryozoans like to attach to seaweed, and others, such as periwinkles, sometimes lay their eggs on it. This is no cause for alarm. Barnacles, bryozoans, and periwinkle eggs are killed as the sea vegetable dries and they can be scraped off or enjoyed as part of the natural goodness of seaweed…they are completely harmless! Figure 7 shows an example of fresh dulse with a few periwinkle egg masses attached. Figures 8 and 9 are examples of bryozoan colonies found on dried kelp (Figure 8) and dried dulse (Figure 9).

Figure 7. Fresh dulse with periwinkle egg masses. When dry these may appear as yellow or white circles

Figure 8. Dried sugar kelp with a heavy over-growth of a yellow bryozoan species. The white dusty patches are classic salts and sugars.

Figure 9. A small piece of dried dulse with a bryozoan attached.

What should I do with moldy seaweed?

A single piece of moldy seaweed does not necessarily mean the entire package is compromised, especially if the rest of the contents are dry and mold-free. Low-moisture foods, such as hard cheeses, are often salvageable by simply cutting away the contaminated area. The low water activity of the rest of the material prevents the mold from spreading. We think this is a preferred solution in line with our philosophy of sustainability and to discourage waste and overharvesting.

Not everyone will be comfortable with this solution, of course. Some people, upon finding a single moldy slice of bread at one end of a loaf, might still go ahead and make toast with the rest. Others, however, might throw the entire loaf away. We respect this very personal decision! Product safety, quality, and customer satisfaction are always top priorities. If you find moldy seaweed in your package upon arrival, please contact customer service through our website https://seaveg.com/pages/contact-us so we can record the incident and offer a refund or replacement when it is warranted. It is always a good idea to examine your seaweed package upon arrival because after someone has had it for a while, we have no way of knowing whether it was exposed to moisture or not. Never throw seaweed away if you are a gardener or have indoor houseplants; it makes a great soil amendment or compost, or it can be steeped in water to make a mineral tea and fed to soil or plants in that fashion.