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Review article

Cheese-Algae Interactions

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Abstract

Algae are everywhere in this planet. They have been used in a wide variety of industries because of unique chemical composition and high concentration of bioactive substances. The agar, alginate and carrageenan are products which come from the gelling, thickening and stabilizing properties of algae. In addition algae is considered to be an important supplement and an additive to handy foods. They are also added up to products of fish and oils, to promote their quality, as well as to meat products like steaks, pastry , frankfurters and sausages. Algae is also used in grain products and their derivatives , like bread, pasta and flour. Because of their critical characteristics algae plays a role in the fermented functional food structure. The majority of fermented products made with algae are dairy products and their derivatives. Mixed fermented products, which contain an intensive population of lactic acid bacteria and algae, contain biologically active metabolites of natural origin, which enables not only the creation of high-nutrient products, but also the creation of a novel types of fermented food.

Keywords: Cheese, Algae, fermentation , dairy products.

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INTRODUCTION

One of the most famous and complex foods today is cheese, due to its special qualities (Almena-Aliste et al,. 2014). It is considered one of the most important dairy products that come in many tastes and textures (Lizzie Streit 2019). On the other hand algae is among the most popular creatures on the planet. They have the ability to develop even though very hard conditions. They exist in both aqueous and terrestrial climates, also they grow in salt and sweet waters (Sylwia Scieszka et al,.2018). Due to its characteristic of algae, it has been used in various industries. like the cosmetic manufacture, the chemical industry, as well as generating bactericidal substances. Furthermore, the major share went to the food industry, which used algae in significantly (Pina- Perez *et al*,. 2017).

Active foods and nutritional supplements are made from them (Borowitzka, 2013). Besides using cheese as an ingredient, which has gained commercial significance in the food industry as a result of its use as a pizza topping, consider incorporating it into appetizers. in pasta dishes as a sauce, and finally present with hamburgers in form of slices (Lucey, 2008). Both, algae and cheese have high nutritional value and their combination constitutes a very valuable dietary duo for proper and healthy body functioning as it works to prevent diseases of the digestive system because it contains inert fibers and a small percentage of energy and due to this feature, it can be used as a weight loser alternative.

Cheese Microorganisms

The microbiota of cheese can be divided into starter LAB, cultures containing adjunct microorganisms, and secondary microorganisms. The 1st set is critical for the acid production during manufacture and also have a part in a process called ripening process, while the other two sets contribute in the ripening. By spontaneous occurring non-starter lactic acid bacteria (NSLAB), the secondary microbiota is formed, other molds, bacteria and yeasts which grow inside or outside in different types of cheese (Cristiane et al,.2008).

Lactic Acid Bacteria

This type of bacteria is abbreviated as LAB. They are a diverse class of bacteria that are required for the proper functioning of a variety of fermentation processes (Bintsis, 2018). Some of the bacteria found in cheese may be homofermentative in nature, like *lactococci*, or heterofermentative, like *lactobacilli*. It has been discovered that different strains of lactic acid bacteria have varying levels of proteolytic activity in cheese. However their essential function appears in the aminic formation and ammoniacal (N) , via peptides degradation and a.a metabolization – During cheese manufacturing process, this type of bacteria, is playing a vital complementary role through breaking down the milk curd protein. The major bacteria contributed to dairy products, especially cheese and various dairy products are shown in Table 1.

Table 1. Major lactic acid bacteria species in cheese (Broome et al., 2003).

Species and Subspecies	**Principal applications / alternative applications**
Lactococcus spp. *Lc. lactis subsp. lactis* *Lc. lactis subsp. lactis biovar diacetylactis* *Lc. lactis subsp. cremoris*	 Starter culture for the production of a variety of cheeses that grows in a warm environment. Used in cheeses such as Gouda and Edam, as well as sour cream and lactic butter. Starter culture for the production of a variety of cheeses that grows in a warm environment.
Streptococcus spp. *S. thermophiles*	 Hard and semi-hard high-cook cheeses, in particular, are made with thermophilic starter cultures, which are found in yogurt and a variety of other dairy products.
Lactobacillus spp.	
Lb. acidophilus	In cheese and yogurt, a probiotic adjunct culture is used.
Lb. delbrueckii subsp. bulgaricus *Lb. delbrueckii subsp. lactis*	Thermophilic yeast starter. There is a preference for hard and semi-hard high-cook cheeses, along with various cheese varieties. Utilized in fermented milks and hard cheeses that require a long cooking time.
Lb. helveticus	Thermophilic starter culture for fermented milks and a wide variety of cheeses, especially hard and semi-hard high-cook cheeses.
Lb. casei	Cheese ripening culture used in conjunction with the primary culture.
Lb. plantarum	Cheese ripening culture used in conjunction with the primary culture.
Lb. rhamnosus	Cheese ripening culture used in conjunction with the primary culture.
Leuconostoc spp. *L. mesenteroides subsp. cremoris*	 Edam, Gouda, fresh cheese, lactic butter, and sour cream are all made with a mesophilic culture.
Brevibacterium spp. *B. linens*	 Utilized to spread surface-ripened cheeses such as Camembert, Stilton, and Limburger as well as an auxiliary culture for cheese ripening.
Propionibacterium spp. *P. acidipropionici* *P. freudenreichii subsp. shermanii*	 Utilized in the production of Gruyère and Emmental cheeses. Utilized in the production of Gruyère and Emmental cheeses.

Characteristics of cheese and algae

Cheese comes in many different styles, texture and tastes, but all of them came from same source which is milk (Meyer, 2014), Diverse cheeses evolved in distinct regions, each influenced by its own culture and environment.

There are numerous methods for making cheese, which have developed with time in line with changing consumer demand and the acceleration of modern technology. Color, aroma, texture, taste, firmness, mold, gas holes or ‘eyes', and keeping qualities of cheeses vary widely. (Fox et al,.2017)

A method for classifying cheese that is universally accepted does not exist., but there are some standards that can be used like area of source, texture and length of ageing. But in general a key to differentiate the characteristics of cheese can be referred to: Milk source, moisture percentage, specific molds and bacteria added, varying lengths of aging (Santiago-Lopez et al 2018). It resulted in the development of numerous cheese varieties, with the International Dairy Federation (Fox,2000), recognizing approximately 500 varieties, Walter and Hargrove mentioning more than 400, Burkhalter mentioning more than 500, and Sandine and Elliker mentioning more than 1,000 (Sulieman et al.,2018).

Algae are photosynthetic eukaryotic organisms that exist in large and diverse gigantic communities. They can be unicellular, multicellular or present in form of the colonies. From spherical cells with a diameter of 0.5 meters to multicellular thalli measuring 60 meters in length, they come in a wide variety of shapes and sizes to choose from. From spherical cells with a diameter of 0.5 microns to cells that are 60 microns in length. (Raven et al.,2014). There are two major types; microalgae or macroalgae. Microscopic single-celled microorganisms known as microalgae can be either prokaryotic (*Chlorocyanobacteria*) or eukaryotic (Green algae) (*Chlorophyta*). Big-size algae that are visible to the naked eye are macroalgae (Khan et al.,2018).

Microalgae species have given a great deal of benefit to various sectors of public life. Because of its nutritional properties, microalgae have been cultivated by humans like *Spirulina*. In addition, it contains various valuable biological active compounds that can be taken from their cells, included sugars, proteins, fats, vitamins and carotenoids. So it can be used in a lot of commercial applications (Tan et al.,2020).

Due to the great algae's distinct properties and its enhancement of human health, which reduces many chronic diseases and even helps its expansion, it has gained unparalleled fame and attention for this in recent years (Elena-Suzana et al.,2020). It can used also as a natural fertilizer in agriculture or be used for wastewater treatment, thus improving the products quality and decrease the need for chemical fertilizers (Biris-Dorhoi et al.,2018, Boukhari, E.L et., 2020).

Algae are similar to plants and animals in some specific general characteristics so that they can carry out photosynthesis like plants. They also have specialized structures and cellular organelles such

as flagella and centrioles, found only in animals. Listed below are some of the general characteristics of algae: they are photosynthetic organisms, present in unicellular or multicellular form, Algae doesn't have leaves or roots or stems which let her in irregular shape, the adequate moisture is the suitable place for algae, according to the reproduction process the algae appear in both forms (sexual and asexual).

A sexual reproduction occurs by spore formation. Algae are creatures that can be in a symbiotic relationship with other organisms. According to certain criteria, the varieties may be grouped or classified into types like cell covering, photosynthetic pigments, reserve products etc (Graham et al., 2008; Lee, 2008) but with no single method being universally used (Barbara Ensrud 1981), nevertheless, no particular strategy is universally adopted.

The most frequently and traditionally used method is based on the pigment and Algae are classified into three major categories:

A phylum of green algae that possess the chlorophyll a and b pigments is referred to as a "*Chlorophyceae*" (examples: *Chlamydomonas*, *Spirogyra*, and *Chara*).

Phaeophyceae algae is primarily found in the marine environment, and the brown variety is known as "*Phaeophyceae*". Carotenoids and xanthophylls are also pigments (examples: *Dictyota*, *Laminaria*, and *Sargassum*).

Rhodophyceae are red algae that contain r-phycoerythrin, a pigment that gives them their red color (examples: *Porphyra*, *Gracilaria*, and *Gelidium*).

Blue-green algae (*Cyanobacteria*) are the fourth type of algae and are occasionally mistaken for seaweed.

This species of algae is quite common in home aquariums. and is referred to as slime algae or smear algae due to its ability to quickly cover all surfaces. (Chandra Veluchamy et al.,2020).

Cheese and algae application in food industry

Since old times, algae species have been used as a source of food. While eating algae has a long history in Asia and the East, interest in algae-based products is relatively new in western countries, but it is growing. (Biris-Dorhoi et al.,2020). novel studies talked about bioactivity of some common species, like *U. pinnatifida* and *H. elongata*, suggest their inclusion in functional food formulations., because of their high composition of antioxidants and the ability to relieve the metabolic syndrome (Rico et al.,2018).

Due to its significant position in the food system, cheese is present in almost every kitchen, regardless of the dish being created. It can be found as an ingredient on a cold buffet or cheese course for dinner or lunch, as a featured item on a hot buffet or cheese course for brunch, or as a cooking cheese

(As an ingredient in the base of a cream sauce, grated for making a cheese sauce, used in hors d'oeuvres, sprinkled on dishes to be gratinated, included in snacks, salads, etc.).

Effect of adding algae on the physical properties of cheese

Apart from their nutritional value, algae have been shown to improve the stability of products over time due to antibacterial and antioxidant compounds presence. In this regard, The food preservation quality of the cheese was proven by incorporating algae Wakame (*U. pinnatifida*) and Kombu (*Laminaria japonica*) into the mix. (Lalic, L.M., et al 2005). For example: In order to produce dairy products as an iodine source, a type of algae known as (*Laminaria saccharina*) was introduced to cottage cheese and fresh cheese from the North Sea. (Cofrades, Serdaroglu, and Jimenez-Colmenero, 2013).

Cheese and Algae Toxicity

Tryptamine, histamine, tyramine, cadaverine putrescine, and phenylethylamine are the major biogenic amines found in cheese. Eating the food which contains some biogenic amine can lead to adverse toxic reactions (O'Brien, N.M. et al.,2004)

In either fermenting and ripening process the changing in cheese includes the manufacture of a highly toxic alkaloid known as roquefortine. It is a neurotoxin that has been shown to cause seizures in mice. likely, roquefortine is present in all blue cheeses. The alkaloid is produced by the mold *Penicillium roqueforti.* Alkaloids, regardless of how little they are diluted, are toxic and will contain various poisons, with hemlock plant poison, coniine, one of the major volatile alkaloids found in hemlock, being one example. Also present are caffeine, the primary alkaloid found in carbonated beverages, black tea, coffee, and chocolate. (Agatha M.2015)

Toxic algae are those types of algae that are responsible for the production of potent toxins. Some other algal species specially the *diatoms* and *dinoflagellates* have strains or varieties which are at times lethally toxic. This usually appears under heavy bloom condition when there are bi amounts of nutrients, a warm temperature and much sunshine (Lawler,1998). The toxic algae classified to two; freshwater toxic algae and marine toxic algae. Brackish and estuarine species are included under marine toxic algae (Gorham, 1988). Dinoflagellates (class *Dinophyceae*) are the most well-known toxin producers. *Alexandrium tamarense* and *Gymnodinium catenatum* are dinoflagellates that produce neurotoxins that cause paralytic shellfish poisoning, and these toxins are responsible for saxitoxin poisoning. Diarrheic shellfish poisoning is caused by okadaic acids produced by a variety of algae, most notably Dinophysis species. Toxins produced by *Gymnodinium breve* cause neurotoxic shellfish poisoning (Band-Schmidt et al.,2019).

Agar, alginate , carrageenan, gum Arabic and cellulose

Numerous algae have a substance called phycocolloids (algal colloids) in their cell walls that can be extracted using hot water. Alginates, agars, and carrageenans are the three major phycocolloids. (Synytsya, Andriy et al.,2015)

Agar

Is most commonly obtained from macroalgae and has numerous applications in foodstuffs, like fruit juices, candies, frozen foods, and deserts., as well as industrial applications such as sizing of paper, printing on textile, and as agarose in molecular biology, as well as in a variety of other biomedical fields for the manufacture of anticoagulants, tablets, and capsules (Poonam Sharma et al.,2017).

Carragenans

Carrageenan is a soluble polysaccharide derived from algae that is primarily used as an emulsifier and stabilizer in different nourishments. Because of their thickening characteristics, -and carrageenans are frequently used in a variety of foods, include products of meat, jams, jellies, and desserts. Numerous pharmaceutical applications of carragenans have also been investigated, including antitumor, anticoagulant, and antiviral.

Alginate

Alginate, a brown algae derived compound, is critical in the textile industry as it is used to size cotton yarn, with its gelling properties being especially valuable. Alginate has the ability to form a viscous solution, and it also has the property of chelation, which could open up the market for pharmaceuticals and food products.

Acacia gum

Also known as gum Arabic is a common ingredient in food because of its ability to affect the consistency, body, and texture of the final product. As a beverage emulsifier, it is most commonly used. (Saha, D., & Bhattacharya, S. 2010). It is a low viscosity gum that produces low viscosity when compared to 1% xanthan or CMC at low shear rates. (Williams and Philips 2000). Mothe and Rao (1999) discovered that dispersions of gum arabic (4–50%, w/v) display shear-thinning features at low shear rates (10 s1) and Newtonian plateaus at shear rates greater than 100 s1. However, it is discovered that the infinite shear rate viscosity () increases with increasing gum content.

Cellulose

As the most prevalent natural substance, cellulose serves as the primary constituent of plant cell walls.

It is a linear polymer with a high degree of polymerization that accounts for the majority of wood's characteristics. Colloidal phenomena are frequently utilized in a variety of industrial manufacturing processes. Suspended cellulose, which is widely utilized in the paper and cellulose industries, has a strong proclivity to aggregate and form clots. (Stygar, Marina. 2020)

Supplements: Because of algal's high nutritional value, they are frequently used as dietary supplements. Chlorella and Spirulina are the most common. Incorporating algae into one's diet provides a source of wholesome proteins. Algae detoxify the body, save the mucosa of gastric, and help in digestion. Algae can also improve memory and concentration, as well as aid in the treatment of diabetes, rheumatic diseases, and arterial hypertension. Additionally, they combat bacterial, fungal, and viral contagions.

Cheese and algae as fertilizers

In order to keep everyone healthy, proper food waste disposal is one of the most critical principles to follow (WHO, 2015).From the most important problems that face the dairy industry is the disposal of expired products.. Expired dairy products such as cheese, yoghurt, milk, must be came back to factories and must be disposed off quickly once the expiration date appears (Dansted, 2016). Milk and dairy products are variously disposed of. They can be dumped on farmland, converted into a solid, and put in a permitted landfill. They can also be trucked to a permitted wastewater treatment plant, or released into a permitted sanitary sewer. (Mamdouh A. Eissa et al.,2018). A high concentration of organic compounds and elements are found in dairy products, and these may be useful to plant nutrition. (Teshome, 2015 and Simun,2012) and failing to recycle these materials causes many disasters, while properly disposing of them has a significant economic impact. Because of the high organic matter and nutrient content, a lot of organic waste is recycled on agricultural lands to be used as organic fertilizer. (Adriano et al.,2012; Chrysargyris and Tzortzakis,2015). Using organic fertilizers boosts crop yield and increases net return, thus improving the quality and supply of plant nutrients. (Scotti et al., 2015; Eissa, 2017) . To increase the quality of the soil, one of the most cost-effective ways is to use organic fertilization. (Scotti et al., 2015).

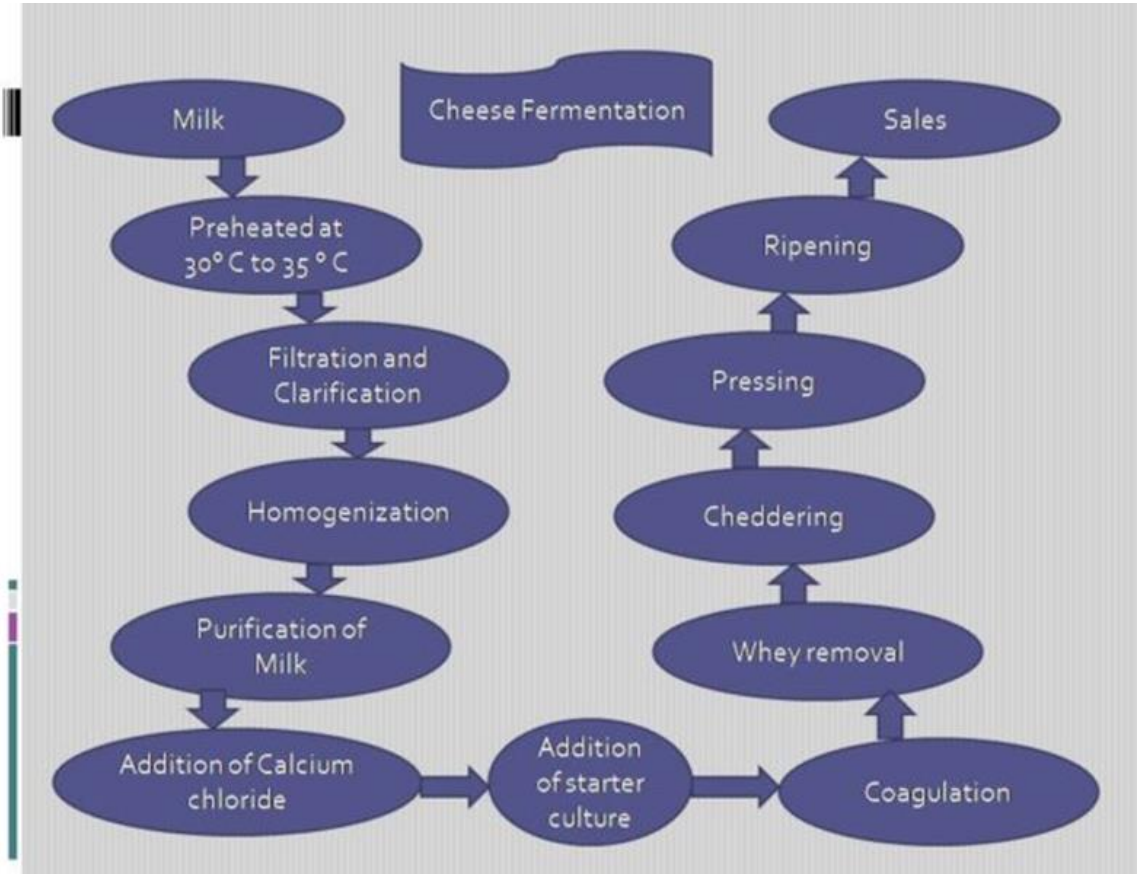
Some novel reports and studies have indicated that different types of photosynthetic microorganisms like *cyanobacteria* and microalgae (MA) can be used as biofertilizers and soil conditioners (Theint Theint Win et al.,2018). For example: Because of it’s unique character the ability of nitrogen-fixing the cyanobacteria consider as the most important biofertilizer.

Fermentation of cheese and algae

Fermentation is a critical process that occurs both in the internal and external environment., during which sugar is consumed in the absence of oxygen and thus energy is produced by microbes when

converting it into chemicals . So – fermentation eats sugar and releases energy. And according to this rule the fermentation in the case of cheese is eating lactose (sugar in milk) and making acid.

Certain organizations and scientists are pursuing an alternative method of growing algae with the use of sunlight: growing them in the dark on sugars, a process known as "heterotrophic" fermentation. Algae convert sugars to oil and biomass, which can be used to make cosmetic chemicals, biofuels, and nutritional products, among other things.



Algae benefits, and its harmful effects

Table 2. Shows Algae benefits, and its harmful effects

Algae benefits	**Harmful effects**	**Reference**
Spirulina (blue green algae) is difficult to toxicity, making it an excellent choice to add to foods or take as a standalone supplement.	The water in city reservoirs is contaminated by a variety of blue-green, green, and other algae. Water that is contaminated with this pollutant has a bad odor and is unsanitary.	Gutiérrez-Salmeán G et al.,2015 Kritika Jain (2021)
Antioxidants found in seaweed have been shown to have some anti-cancer properties, according to research.	Cephaleuros virescens is not a fungus, but an algal form that causes the well-known ailment "red rust of tea."	Koníčková R et al.,2014 Kritika Jain (2021)
The high fiber content in a dose of seaweed may also be beneficial to weight control and obesity prevention by reducing fat digestion, according to research.	Algae present on other plants and trees inhibit photosynthesis and have a negative impact on their growth.	Newcastle University. (2010, March.) Kritika Jain (2021)
Both lutein and zeaxanthin, antioxidant carotenoids found in microalgae, improve eye and brain health as well as disease prevention.	The algae clog the fish's gills, preventing them from breathing during the night and causing a complete depletion of oxygen.	McKel Kooienga 2018 Kritika Jain (2021)

CONCLUSION

Dairy products and their derivatives are rich materials, especially cheeses, and this richness increases even more when add various algae to it for increasing the nutritional value, which allows when combined them together with food to produce healthy products full of beneficial nutrients.

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