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| Dehydrated Greek Yogurt |
| Spray Drying of Greek Yogurt |
| Group 1 |

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| Kathryn Atherton  10-12-2018 |

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# Unit Operations and Group Members

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# Goals of Spray Drying

Spray drying is a process in which a product is converted from a liquid to a powder by removing moisture from the product. The product is atomized and exposed sprayed into a chamber of hot air which removes the water content from the product without allowing it to reach a temperature higher than the wet bulb temperature of the drying air (Okos, Drying Equipment, 2018). This process is beneficial for industrial production and storage of products because it increases the shelf-life of the product without requiring refrigeration, which also reduces the cost of shipping (Yilmaz, Sert, & Karakaya, 2010; Bylund, 2003). In addition, because the product never reaches a very high temperature, there is minimal damage to the microstructure due to heating, leading to a high-quality product following rehydration (Rascon-Diaz, Tejero, Mendoza-Garcia, Garcia, & Salgado-Cervantes, 2012; Yilmaz, Sert, & Karakaya, 2010).

# Methods

Spray drying is one of the principle methods of drying in the dairy industry. The process works by concentrating the milk via evaporation then drying in a spray tower (Bylund, 2003). There are three steps in the process of spray drying. First, the yogurt is atomized, then the droplets are dried in the heated air for three to 30 seconds, and finally the particles are separated from the hot air. The liquid yogurt is atomized with a rotating wheel atomizer which spins or a pressure nozzle, pulling in the product to the center with centrifugal force. Droplet shape is determined by the shape of the vanes in the wheel and the rotational speed of the wheel (Equation 1, (Okos, Campanella, Narsimhan, Singh, & Weitnauer, 2007)) or the pressure drop across the spray nozzle (Equation 2, (Okos, Campanella, Narsimhan, Singh, & Weitnauer, 2007)). Rotating wheel atomizers produce particles in the range of 1-600 μm and pressure nozzles produce particles in the range of 10-800 μm (Okos, Campanella, Narsimhan, Singh, & Weitnauer, 2007).

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# Process Inputs and Outputs

The yogurt entering a spray drying process has very strict requirements on the number of bacteria per gram; the final dried product must not exceed 50,000 bacteria per gram, or 5,000 bacteria per liter once reconstituted. This is especially important for heat-resistant bacteria as they may multiply during evaporation and change the balance of the probiotics in the yogurt (Bylund, 2003). The final powder product has a protein content of 33 to 36%, an increase from an average of 22% prior to drying (Gerdes, 2009).

The outlet temperature of the air into the drying column is the most important factor that affects the properties of the yogurt, including the survival of bacteria and color change. A lower air temperature, specifically 60.5°C, was significantly correlated with the ideal qualities of the final product (Koc, Sakin-yilmazer, Kaymak-ertekin, & Balkir, 2014). This does, however, mean that the droplets must stay for a longer period of time in the dryer.

# Effect of Spray Drying on Product

Spray drying produces particles that are mostly spherical with crater-like structures. The particle size distribution is normal with a peak at 3.053 μm. The particles are highly soluble (68.7%), dense (538 kg/m3), and somewhat porous (36.54%). When drying with very hot air (85°C), it was noted that the sensory properties, specifically color, changed and were less accepted by consumers (Koc, Sakin-yilmazer, Kaymak-ertekin, & Balkir, 2014).

Traditional yogurt typically lasts two to three weeks before spoiling. One study found using sorption isotherms, however, that powdered yogurt will has more than double the shelf life of traditional yogurt (Dibyakanta, Dash, Mishra, & Deka, 2018). The authors determined adsorption isotherms of a spray-dried yogurt powder with static gravimetric technique at four different temperatures and fit the data to eight sorption models. The GAB model was used to find the moisture content at each temperature. Heat of sorption and Gibb’s free energy change was also calculated. The powder’s storage stability was studied in two types of packaging and it was found that the shelf life of powdered yogurt can reach up to 45 days in aluminum laminated polyethylene packaging.

In addition to the shelf life being affected by the increased air temperature, research has shown that the number of microorganisms in the yogurt decreases with increased air temperature as well as increased pressure drop across the pressure nozzle. The ideal conditions for producing acceptable dried particles while retaining survival of two bacterial species, *Streptococcus salivarius* *thermophilus* and *Lactobacillus debrueckii bulgaricus*, were found to be an air temperature of 60°C and a pressure drop of 98 kPa across the atomizer. These conditions are not perfect, however, as freeze-drying was found to have a higher survival rate for these specific bacterial species (Kim & Bhowmik, Survival of lactic-acid bacteria during spray drying of plain yogurt, 1990). A similar study found that the air temperature of 60°C was also the optimal temperature for retaining lactic acid bacteria and other sensory attributes including color and moisture content (Koc, Yilmazer, Balkir, & Ertekin, Spray Drying of Yogurt: Optimization of Process Conditions for Improving Viability and Other Quality Attributes, 2010).

The two main flavor components of yogurt, acetaldehyde and diacetyl, are heat sensitive and can degrade during the drying process. As spray drying requires a lower temperature than most drying processes, this is not a large concern, but it was found that the flavor of the dried yogurt was improved when whey protein concentrate was added to the yogurt during the fermentation process when the pH reached 4.6. This increased the acetaldehyde content of the yogurt to offset the losses created during spray drying (Anonymous, 2005).

# Alterative Drying Methods

## Freeze-Drying

Freeze-drying is a method by which a product is frozen and then pressure is reduced during heating to allow the ice in the material to sublimate. This method is advantageous for drying yogurt because it creates a more nutritious product with a similar texture to normal yogurt once it is rehydrated than other methods of drying. In addition, the process has a higher rate of survival of critical bacteria survival than spray drying, specifically lactic acid bacteria. Finally, it is more widely accepted by consumers than other forms of dried yogurt, it can dry yogurt products with added ingredients such as fruit or nuts, and it has a longer shelf-life, so it is ideal for industrial processing of yogurt for sale (Sakin-yilmazer, Dirim, Di Pinto, & Kaymak-ertekin, 2014).

However, freeze-drying is more expensive than other drying processes (Kim & Bhowmik, Moisture Sorption Isotherms of Concentrated Yogurt and Microwave Vacuum Dried Yogurt Powder, 1994). It also creates a product with a lower moisture content, which can increase the rates of spoilage reactions due to the higher reactant concentrations. Finally, while it retains a higher number of lactic acid bacteria than other forms of drying, it still loses some colonies compared to traditional yogurt (Kim & Bhowmik, Survival of lactic-acid bacteria during spray drying of plain yogurt, 1990).

## Microwave Vacuum Drying

Microwave drying is a process by which microwave radiation generates heat as the pressure of the chamber is reduced (Scaman, Durance, Drummond, & Sun, 2014). It is advantageous as it has a lower spoilage rate as compared to traditional yogurt because of a lower level of equilibrium moisture content (Kim & Bhowmik, Moisture Sorption Isotherms of Concentrated Yogurt and Microwave Vacuum Dried Yogurt Powder, 1994). However, the differences between microwave vacuum drying and other forms of drying are not very significant when drying yogurt specifically (Sengupta & Bhowal, 2017). Additionally, as this is a new technology, the equipment is much more expensive than that of more traditional methods (Scaman, Durance, Drummond, & Sun, 2014).

## Refractance Window Drying

Refractance window drying is a process by which …. It is advantageous as it has better physical properties than freeze-dried yogurt. In addition, it requires a lower production temperature than spray-drying, which also infers that the physical properties will not be affected by heat (Tontul, Ergin, Eroglu, Kucukcetin, & Topuz, 2018). However, the dried yogurt product has a less pleasing color and the yogurt bacteria counts are lower than dried yogurt produced by other methods (Tontul, Ergin, Eroglu, Kucukcetin, & Topuz, 2018).

# Conclusions

Spray drying is the industrial standard process for creating dehydrated dairy products. Though it has a negative effect on the sensory properties and survival of important probiotic bacteria, it is efficient and effective for creating a yogurt product with a longer shelf life. Additionally, steps can be taken in earlier processes of the yogurt creation to counteract the detrimental effects of spray drying on the yogurt product. Literature consistently shows that the optimal temperature of the air to heat the droplets of yogurt while causing minimal damage on the product is 60°C and the pressure drop across the spray nozzle should be about 98 kPa.

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