The next step of pasta processing is drying. The goal of drying process is to remove the moisture content in the dough, so that the final product has an extended shelf-life and can be stored for quite a long time. Besides that, removal of water can also secure the food safety because as we know, microbes grow in the food where water activity is high, this is why we have to remove the water and make a smaller percentage of moisture content [1]. This drying process is also one of the important steps in the pasta processing because this step has a really big effect in the final product. Due to the use of high temperature in this step, we have to be very careful, so that the final product is still marketable and being desired by consumers. Therefore, we have to have a good appearance and quality of the product, as well as preventing the loss of nutrients during the process [3].

The initial moisture content of the dough is 30% [2] and while they are in the extruder, it will have a very little reduction in the moisture content, which can be ignored. The final moisture content of the pasta will be 12% [1]. Using the equation of wet basis moisture content and mass balance, we will know how much mass of water left in the final product, hence we know how much water has to evaporate in the dryer, and also we will know how much input we have to use based on the mass of solids.

Wet basis moisture content:

$$MC_{wb}\ \% = \frac{mass\ of\ water}{mass\ of\ solids + mass\ of\ water} \times 100\%$$

Mass balance:

mass of solid in input = mass of solid in output

There are four factors that affect the drying process. The four of them are humidity, temperature, time, and air flow rate. The air that is used to dry the product is wet hot air and the air is directly interacting with the product. This is why we need to control the humidity of the air, so that our product will still meet the requirement of the final moisture content [3]. We are using wet hot air in order to prevent cracking of the product while being passed through a high temperature dryer. So, it will be around 40-70% (w/w) of the humidity in the air [3]. The temperature itself has to be hot enough to dry the pasta, but cold enough not to damage the product or destroy the nutrients. This can be done by step-wise process, instead of just one step

process [2]. The temperature that is used is different depending on the other factors and the process step, but it is usually around 32-110 °C [5]. One of the other factors that can influence the temperature is time. The longer time you have, the lower the temperature, and vice versa. Time is one of the basic factors that affect the two other factors, which are humidity and temperature [3]. It has the same significant control as air flow rate. Usually, the air that is used in the process has a direct interaction. It is the most efficient way to have a direct contact with the product because then, it will have a bigger surface area of the product that is exposed to air, which makes a faster drying process.

There are three steps of drying, which are pre-drying, drying, and cooling [2]. The first step is pre-drying. Pre-drying is a step where we apply the hot air for 30-60 minutes before actually drying it. The temperature is usually between 55-82 °C [2]. It can be varied depending on the type of pasta. There are two types of pasta that can be made. They are short and long pasta. There is not much difference between the drying processes of the 2 types. The different is in pre-drying and drying steps. For the short pasta, it requires a shaking pre-dryer and a shorter time for drying step because it has lesser surface area of the product, whereas, the long pasta, it requires a blast air for pre-drying and a longer time, as well as the steps for the drying stage because it has a bigger surface area to dry [5]. There are two important effects that we can get from this pre-drying step. The first one is to prevent the pasta to stick together [4]. This can happen because in this step, we reduce at least 17% of the moisture content [5], hence, the surface of the pasta will be dried, while the inside of it, will still be wet. Therefore, it will prevent the pasta to stick together. The last effect is for the final product not to crack [2]. This can happen because in the pre-dryer, the heat is not as hot as in the dryer, so the pasta will get used to the heat and it will slowly dry it, which can be seen by the drying of only the outer part of the pasta. This is called moisture gradient [4]. By having moisture gradient, we can make the dryer's "job" easier by lowering the energy, temperature, and time that are required, hence, giving better final product.

The next step is drying. Drying is the step where we get the desired moisture content in the final product. As we mentioned before, the air that we used in the dryer is wet hot air with the temperature around 70-104 °C for 15-120 minutes [3]. We can calculate the energy that is required for this step by using the energy transfer equation.

Energy transfer: $Q = m.Cp.\Delta T$ → no phase change

$$Q = m.\lambda$$ → phase change

When determining the time that is used in the drying step, we have to consider the side effect that affects the product. If the process is too slow, the dough will have moulds within the product due to the slow drying of the inner part . When the inner part is dried too slowly, it will have a high water activity, which means that moulds can grow on that part. The other side effect is if the process is too fast, the dough will crack and result in bad look of the final product that does not desire by the consumers. That is why we prevent it by doing the pre-drying step, resulting in moisture gradient [4]. Besides drying the process to the desired moisture content, this step can also be used to enhance the color of the pasta, which is yellow. By using a high temperature, there will be more yellow color given that the Minolta b will increase. Minolta b is the marker of a better yellowness. This can happen because the lipoxygenase, the bleaching enzyme that found in the dough, is not active as usual [5]. In addition to making the color appealing to the consumer, high temperature can also use for sterilization of the product [1].

The last step is cooling. Cooling is the process to prevent the loss of nutrients due to the high temperature in dryer [2]. We used water for cooling with the temperature of 28-32 °C for about 1.5 hours and they are not directly interacting [5]. In this cooling process, there is energy that is released by the product to the water. We can calculate the energy by using the energy transfer equation that is mentioned before. Furthermore, cooling is used to return the temperature of the product to the normal one [1], so that it can be put into packaged right away. If we don't cool it first, there might be a reaction between the package and the product, resulting in the damaged package or contaminated product.

References

[1] Food-Info.net. (2010) the Industrial Production of Pasta. http://www.food-info.net/uk/products/pasta/production.htm

[2] Kent, N. L. and Evers, A. D. (2001) Pasta and Whole Grain Foods, chapter 10: *Technology of Cereals*, 4th Edition, pp. 233–243.

[3] Migliori, Massimo, et al. (2005) Modelling of High Quality Pasta Drying: Mathematical Model and Validation, J. Food Engineering, 69: 387–397.

[4] United States Environmental Protection Agency. (1995) Food and Agricultural Industries, chapter 9: *AP 42*, 5th edition, volume 1, pp. 9.9.5-1 to 9.9.5-3.

[5] Marchylo, B. A. and Dexter, J. E. (1989) Pasta Production, chapter 6: *Cereals Processing Technology*, pp. 109-130.